Introduction

The Mississippi Water Resources Research Institute (MWRRI) provides a statewide center of expertise in water and associated land use and serves as a repository of knowledge for use in education, research, planning, and community service.

The MWRRI goals are to serve public and private interests in the conservation, development, and use of water resources; to provide training opportunities in higher education whereby skilled professionals become available to serve government and private sectors alike; to assist planning and regulatory bodies at the local, state, regional, and federal levels; to communicate research findings to potential users in a form that encourages quick comprehension and direct application to water related problems; to assist state agencies in the development and maintenance of a state water management plan; and to facilitate and stimulate planning and management that: deals with water policy issues, supports state water agencies' missions with research on problems encountered and expected, and provides water planning and management organizations with tools to increase efficiency and effectiveness.
Research Program Introduction

The Mississippi Water Resources Research Institute (MWRRI) conducts an annual, statewide competitive grants program to solicit research proposals. Proposals are prioritized as they relate to the research priorities established by the MWRRI Advisory Board and by their ability to obtain Letters of Support or External Cost Share from non-federal sources in Mississippi. The MWRRI’s External Advisory Board then evaluates all proposals. Based on the most current list of research priorities, these would include: water quality, surface and groundwater management, water quality management and water resources development, contaminant transport mechanisms, wetlands and ecosystems, groundwater contamination, as well as other issues addressing coastal and marine issues linking water associations through the state, and institutional needs that include capacity building and graduate student training.
**Natural Enhanced Transport of Agricultural Pb and As Through Riparian Wetlands**

**Basic Information**

<table>
<thead>
<tr>
<th><strong>Title:</strong></th>
<th>Natural Enhanced Transport of Agricultural Pb and As Through Riparian Wetlands</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Project Number:</strong></td>
<td>2007MS61B</td>
</tr>
<tr>
<td><strong>Start Date:</strong></td>
<td>3/1/2007</td>
</tr>
<tr>
<td><strong>End Date:</strong></td>
<td>8/31/2009</td>
</tr>
<tr>
<td><strong>Funding Source:</strong></td>
<td>104B</td>
</tr>
<tr>
<td><strong>Congressional District:</strong></td>
<td>1st</td>
</tr>
<tr>
<td><strong>Research Category:</strong></td>
<td>Ground-water Flow and Transport</td>
</tr>
<tr>
<td><strong>Focus Category:</strong></td>
<td>Wetlands, Sediments, Non Point Pollution</td>
</tr>
</tbody>
</table>

**Publication**

Principal Investigators: Gregg R. Davidson
SECTION I: Contact Information

Project Title: Natural enhanced transport of agricultural Pb and As through riparian wetlands
Principal Investigator: Gregg Davidson
Institution: University of Mississippi
Address: Geology & Geol. Engr., Carrier 118, University, MS 38677
Phone/Fax: 662-915-5824
E-Mail: davidson@olemiss.edu

SECTION II: Programmatic Information

Approximate expenditures during reporting period:

Federal: $9,400, Non-Federal: $18,800, Cost Share: 2:1

Equipment (and cost) purchased during reporting period: none

Progress Report (Where are you at in your work plan):

(4/1/08 – 6/30/08) Two sets of cores from Hampton Lake have been collected and sectioned into 1 cm intervals. Each interval was weighed and dried. Two cores were selected for detailed elemental analysis. Results identified a deep zone with elevated As, Co., Cu, and Ni, but not Pb. Intervals from the zone of elevated metals and from adjacent zones with background concentration have been processed for sequential extraction to determine if the elevated concentrations are associated with a particular sediment phase. Attempts to collect wetland cores failed and another attempt will take place this summer. Most of the expenses reported for this quarter are associated with student stipends and summer salary for the PI.

(7/1/08 – 9/30/08) Sequential extractions of sediment from the open water region of Hampton Lake were successfully completed and now await analysis for trace metals. An additional deep core was also collected from the open water region which has been sectioned, dried, crushed and digested in preparation for element analysis along with the sequential extractions. After several failed attempts to get a wetland core, a core was finally collected and has been sectioned and dried. Crushing for isotope dating and element analysis is in process. If a zone is identified with elevated element concentrations, sequential extractions will also be performed on this core.

Most of the expenses for the previous quarter (4/1/08 – 6/30/08) were for student help, and for materials and supplies associated with the sequential extractions or sample processing.

(10/1/08 – 12/31/08) A wetland core from Hampton Lake was successfully acquired, sectioned and dried. Portions were submitted for $^{208}$Pb analysis to determine sedimentation rates and results have been received. Remaining sediment has been crushed and digested and is awaiting analysis by ICPMS. Sequential extractions performed during the previous quarter were analyzed for trace elements by ICPMS. A bathymetry analysis at Hampton Lake was performed.
by YMD as a third party contribution; documentation has been attached.

Completion of all analyses for cores from open water and wetland cores is anticipated by the end of the grant cycle (Feb 28), though it may prove necessary to sample one additional core from a wetland environment after this date (no additional expenditures from this grant).

(1/1/09 – 3/31/09) At the time of final report preparation, an instrumental problem was discovered that has raised questions about the validity of data acquired over the last six months. As a result, these samples will be re-analyzed to ensure that the results are meaningful. No additional funds are required to do the analyses, just time. A six-month no-cost extension has been requested to complete this work.

Problems Encountered:
(4/1/08 – 6/30/08) Filters approved by the manufacturer for use with the sequential extractions failed when exposed to hydrogen peroxide. New filters are being ordered to redo the sequential extractions. The coring method successfully used to obtain cores from the lake failed to work in the wetland at Hampton Lake. A new coring method will be employed on the next trip to collect the cores.

(7/1/08 – 9/30/08) The wetland sediments proved very difficult to core by conventional methods. Four attempts were required before a core of sufficient length was recovered.

10/1/08 – 12/31/08) The wetland sediments proved very difficult to core by conventional methods. Four attempts were required before a core of sufficient length was recovered. A large range in trace element concentrations is required multiple dilutions and repeated analyses for the same samples that is requiring more time than expected.

(1/1/09 – 3/31/09) At the time of final report preparation, an instrumental problem was discovered that has raised questions about the validity of data acquired over the last six months. As a result, these samples will be re-analyzed to ensure that the results are meaningful. No additional funds are required to do the analyses, just time. A six-month no-cost extension has been requested to complete this work.

Publications/Presentations (Please provide a citation and if possible a .PDF of the publication or PowerPoint):

A presentation was made at the national Geological Society of America meeting in Houston in October, 2008.


This work was presented to the faculty and student body at the University of West Georgia this spring as part of their professional seminar series, and as a recruiting aid.

Student Training (list all students working on or funded by this project)

<table>
<thead>
<tr>
<th>Name</th>
<th>Level</th>
<th>Major</th>
</tr>
</thead>
<tbody>
<tr>
<td>William Walker</td>
<td>MS student</td>
<td>Hydrology</td>
</tr>
<tr>
<td>Steven Utroska</td>
<td>BS student</td>
<td>Geological Engineering</td>
</tr>
<tr>
<td>Frank Roecker</td>
<td>BS student</td>
<td>Geological Engineering</td>
</tr>
</tbody>
</table>
Next Quarter Plans:
(4/1/08 – 6/30/08) Second attempt for sediment core collection within the wetland surrounding Hampton Lake.

(7/1/08 – 9/30/08) Second attempt with new filters for sequential extraction of high and low trace element concentration intervals.

(10/1/08 – 12/31/08) Analyze sequential extractions and digested samples from the open water region of the lake.

Crush, digest and analyze samples from the new wetland core.

(1/1/09 – 3/31/09) Analyze digested samples from wetland core. Repeat analysis of previous samples at higher dilution.

(4/1/09 – 6/30/09) Re-analyze core samples that have already been collected.

Section III. Signatures

Project Manager

Date
Water Quality and Floristic Habitat Assessments in the Coldwater and Sunflower River Basins: Comparing traditional measures of water and habitat quality to Index of Biotic Integrity findings

Basic Information

<table>
<thead>
<tr>
<th>Title:</th>
<th>Water Quality and Floristic Habitat Assessments in the Coldwater and Sunflower River Basins: Comparing traditional measures of water and habitat quality to Index of Biotic Integrity findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Number:</td>
<td>2007MS62B</td>
</tr>
<tr>
<td>Start Date:</td>
<td>3/1/2007</td>
</tr>
<tr>
<td>End Date:</td>
<td>2/29/2009</td>
</tr>
<tr>
<td>Funding Source:</td>
<td>104B</td>
</tr>
<tr>
<td>Congressional District:</td>
<td>3rd</td>
</tr>
<tr>
<td>Research Category:</td>
<td>Water Quality</td>
</tr>
<tr>
<td>Focus Category:</td>
<td>Wetlands, Water Quality, Management and Planning</td>
</tr>
<tr>
<td>Descriptors:</td>
<td></td>
</tr>
<tr>
<td>Principal Investigators:</td>
<td>Todd Tietjen, Gary N. Ervin</td>
</tr>
</tbody>
</table>

Publication
PROJECT TITLE: Water Quality in the Coldwater River Basin: Comparing Traditional Measures of Water and Habitat Quality to Index of Biotic Integrity Findings

Principal Investigator: Todd Tietjen & Gary N. Ervin
Institution: Mississippi State University
Address: PO Box 9690
Mississippi State, MS 39762

Abstract:
The US Army Corps of Engineers in conjunction with the Mississippi Department of Environmental Quality has worked to determine the quality of water in the streams of the Mississippi Delta region using an Index of Biotic Integrity (IBI) approach. This approach to water quality monitoring seeks to use information extracted from fish community composition and habitat parameters to provide an integrated and comprehensive picture of water quality that is reported to be superior to traditional grab samples analyzed for chemical water quality parameters. We have been working to collect water samples from a subset of these sampling sites and analyzing this water using traditional measures of water quality. These samples have been analyzed for a variety of chemical (Nitrite+Nitrate-Nitrogen, Ammonium-Nitrogen, Soluble Reactive Phosphorus, Oxygen, pH), biological measures (Total Coliform bacteria, Fecal Coliform bacteria, Chemical Oxygen Demand), and physical measures (suspended sediments, temperature). We compared these data sets by examining correlations between IBI scores and quantitative measures of water quality. This approach did not help substantiate the value of the IBI approach or provide guidance for mitigation and restoration activities that likely would benefit these streams.

Data:
Raw data are presented in table 1.
Figure 1 displays the locations of the sampling sites used in this study. Sites marked in red were those with IBI scores of 13 or less and sites marked in blue were those with IBI scores above 13. Overall IBI score for the 2 sites ranged from 9 to 20.
Data from earlier wetland plant investigations were reported previously in our 2007 final report.

Results:
Linear relationships for select parameters compared to IBI scores for the sampling location are presented in Figure 2.

Temperature: The relationship between temperature and IBI score is basically flat, suggesting little relationship between the measures. Given the limited range of temperatures encountered this finding was not unexpected. It was hoped that temperature might serve as a surrogate measure for canopy cover or land use characteristics, based on these results there is little suggestion that these relationships would be informative.

Dissolved Oxygen: The overall relationship between dissolved oxygen concentrations and IBI score is negative, with increasing IBI score associated with lower dissolved oxygen concentrations. However this relationship is misleading for 2 reasons; first there are 3 highly
influential data points in the lower right quadrant that shifted the slope of the line negative. These 3 points had lower dissolved oxygen concentrations then would have been expected. If these points are not included there would have been a positive relationship with dissolved oxygen concentrations, a finding better supported by the literature. The fish used in the IBI analysis are, in part, scored based on their environmental tolerances of which dissolved oxygen is an essential component, higher quality fish require higher dissolved oxygen concentrations. The second factor that causes the dissolved oxygen data to be potentially misleading is that the majority of the data used in this analysis involved dissolved oxygen concentrations that exceeded saturation. This is not uncommon in stream systems that usually are kept near saturation by flow-induced introductions of atmospheric oxygen and supplemented by photosynthetically provided oxygen. Once oxygen concentrations approach saturation there is little added benefit to biota from supersaturation.

Turbidity: The relationship between turbidity and IBI scores is the opposite of that which was expected. As with the dissolved oxygen data there were 4 points in the lower right quarter that appeared to be lower than would have been expected. The broader relationship tended to suggest that IBI scores increased with higher levels of turbidity. High levels of turbidity are generally associated with poor water quality conditions and poor fish communities. It is possible that certain turbidity tolerant fish species could dominate these systems resulting in the observed trend.

Suspended Sediments: Suspended sediments are directly related to turbidity as the measurements both (in different ways) evaluate material in the water column. In general the same relationship is observed in the turbidity and suspended sediment data. The suspended sediment data do not show the same degree of upward trend as turbidity was more profoundly impacted by the highest measured values.

Ammonia, Nitrate, and Phosphorus: Collectively the relationship between this group of inorganic nutrients would be expected to be strongly negative. Usually high concentrations of these constituents is associated with extremely high levels of periphyton and macrophytic growth. While moderate growth is essential for providing organic matter needed for metabolism, high levels of production produce extreme diurnal dissolved oxygen concentration variability that is deleterious to fish. The data presented here do not suggest that this occurred as the linear relationships were generally only slightly positive or negative. The moderated impact of these inorganic nutrients is likely a result of the high inorganic turbidity which reduces light penetration needed for photosynthetic growth. Alternatively the sediments may not provide an appropriate substrate for growth.

Chemical Oxygen Demand: Chemical oxygen demand is a measure of organic compounds dissolved in the water that can be oxidized chemically. It is similar to biochemical oxygen demand, except that the oxidation is performed chemically. In general the negative relationship between chemical oxygen demand and IBI scores is as would have been anticipated, lower levels of organic matter were associated with higher quality fish assemblages. There is a cluster of 3 values at middle IBI levels that had disproportionately high chemical oxygen demands. The exclusion of these points would have improved the overall relationship.
Total and Fecal Coliform Bacteria: Coliform bacteria are used as indicators of water quality in streams that are susceptible to loading from waste products of warm blooded organisms. As is apparent in table 1 and figure 2 total coliform concentrations were greater than the upper detection limit, 200 cells ml⁻¹, in all samples collected. This prevented us from obtaining information from this parameter. Fecal coliforms are a subset of the total coliform and while they were less frequently above the upper detection limit, the explanatory value of this data is extremely low. Taken as a whole the coliform data do not suggest high quality, un-impacted waters in the Coldwater Basin.

Recommendations:
Further refinement of the IBI procedures are needed prior to their use as surrogate measures of water quality. The extremely low level of correlation between traditional measures of water quality and IBI scores were worse than anticipated. While the IBI procedure is defined by its ability to integrate water quality over long periods of time by using the fish community as an indicator was expected to result in relatively low levels of correlation, the extremely poor correlations were unexpected. A review of any of the parameters considered demonstrated that high or low levels of the parameter can be associated with high or low IBI scores. It may be necessary to re-evaluate the IBI scoring criteria in light of these results.

Presentations:

Students:
Christopher Doffitt Ph.D. Student Biological Sciences
D. Christopher Holly Ph.D. Student Biological Sciences* graduated August, 2008
Hawken Brackett Undergraduate Wildlife and Fisheries
Erica Schlickeisen Ph.D. Student Wildlife and Fisheries
Dustin Whitehead Undergraduate Wildlife and Fisheries
Lucas C. Majure M.S. degree Biological Sciences* graduated August, 2007
Figure 1. Location of sampling sites in the Mississippi Alluvial Valley. Sites marked in red were those with IBI scores of 13 or less and sites marked in blue were those with IBI scores above 13. Overall IBI score for the 2 sites ranged from 9 to 20.
Figure 2. Water quality parameters plotted against their corresponding IBI scores. Lines represent linear relationships between the parameters.
Table 1. Raw data used in this analysis.

| Site | IBI Score | Temperature °C | Specific Conductance µS cm⁻¹ | Dissolved Oxygen mg O₂ L⁻¹ | pH | Turbidity NTU | Dissolved Oxygen % Saturation | Total Coliform Cells 100 ml⁻¹ | Fecal Coliform Cells 100 ml⁻¹ | Suspended Sediments mg L⁻¹ | Ammonia mg N L⁻¹ | Nitrate mg N L⁻¹ | Phosphate mg P L⁻¹ | Silica mg Si L⁻¹ | Chemical Oxygen Demand mg L⁻¹ |
|------|-----------|----------------|-----------------------------|-----------------------------|----|---------------|-------------------------------|-------------------------------|--------------------------|------------------------|----------------|----------------|----------------|----------------|----------------|------------------|
| 1    | 13        | 8.07           | 199                         | 17.64                       | 8.29| 198.9         | 150.3                         | 200                          | 200                      | 200                    | 100          | 3.88          | 1.15           | 1.2            | 7               | 73               |
| 2    | 13        | 8.01           | 213                         | 14.20                       | 8.00| 194.6         | 120.84                        | 200                          | 200                      | 200                    | 172          | 3.24          | 1.03           | 0.4            | 7               | 52               |
| 3    | 11.7      | 8.17           | 177                         | 17.03                       | 7.87| 154.2         | 145.51                        | 200                          | 200                      | 200                    | 149          | 2.41          | 0.38           | 0.2            | 9               | 18               |
| 4    | 11        | 9.46           | 236                         | 15.43                       | 7.74| 62.8          | 135.98                        | 200                          | 200                      | 200                    | 70           | 3.5           | 0.45           | 0              | 3               | 26               |
| 5    | 19        | 4.4            | 127                         | 19.65                       | 8.38| 28.6          | 152.6                         | 200                          | 15                       | 24                      | 3.04         | 0.3           | 0.1            | 7              | 14               |
| 6    | 8.5       | 6.65           | 252                         | 20.79                       | 8.00| 37.2          | 171.07                        | 200                          | 56                       | 50                      | 4            | 0.1           | 0.1            | 6              | 32               |
| 7    | 14        | 4.14           | 172                         | 19.45                       | 8.78| 172.1         | 150.01                        | 200                          | 200                      | 200                    | 149          | 3.07          | 0.42           | 0.2            | 10              | 20               |
| 8    | 15        | 4.58           | 202                         | 17.88                       | 8.16| 123           | 139.56                        | 200                          | 119                      | 124                    | 4            | 0.32          | 0.4            | 9              | 27               |
| 9    | 12        | 3.38           | 685                         | 22.07                       | 8.66| 103.7         | 167.16                        | 200                          | 130                      | 149                    | 4            | 0.27          | 0              | 5              | 30               |
| 10   | 14        | 3.13           | 126                         | 24.57                       | 8.38| 138.4         | 184.49                        | 200                          | 48                       | 136                    | 4            | 0.16          | 0              | 8              | 69               |
| 11   | 11        | 5.05           | 295                         | 18.90                       | 7.92| 93.4          | 149.4                         | 200                          | 200                      | 94                      | 4            | 0.39          | 0              | 8              | 34               |
| 12   | 16        | 3.6            | 175                         | 19.89                       | 8.19| 204.8         | 151.23                        | 200                          | 102                      | 182                    | 4            | 0.18          | 0              | 10             | 27               |
| 13   | 11.5      | 3.26           | 143                         | 18.02                       | 7.77| 110.8         | 135.75                        | 200                          | 66                       | 127                    | 4            | 0.78          | 0              | 5              | 15               |
| 14   | 17.5      | 3.98           | 97                          | 21.20                       | 8.28| 565           | 162.81                        | 200                          | 200                      | 264                    | 4            | 0.28          | 0              | 1              | 11               |
| 15   | 18        | 11             | 104                         | 7.54                        | 7.93| 6.7           | 68.94                         | 200                          | 74                       | 26                      | 4            | 0.07          | 0              | 9              | 22               |
| 16   | 18        | 5.84           | 85                          | 11.89                       | 8.35| 20.3          | 95.83                         | 200                          | 21                       | 21                      | 4            | 0.15          | 0              | 4              | 8                |
| 17   | 20        | 6.12           | 174                         | 19.83                       | 7.95| 27.3          | 160.98                        | 200                          | 89                       | 89                      | 4            | 0.15          | 0              | 4              | 8                |
| 18   | 17        | 9.94           | 82                          | 9.43                        | 7.79| 25.1          | 84.08                         | 200                          | 166                      | 37                      | 2.96         | 0.21          | 0              | 6              | 7                |
| 19   | 17        | 4.82           | 67                          | 20.17                       | 8.14| 28.9          | 158.32                        | 200                          | 200                      | 200                    | 4            | 0.15          | 0              | 4              | 8                |
| 20   | 12        | 13             | 119                         | 12.93                       | 7.83| 88.8          | 123.59                        | 200                          | 200                      | 106                    | 3.16         | 0.19          | 0              | 5              | 28               |
| 21   | 12        | 6.76           | 87                          | 22.25                       | 7.81| 323.7         | 183.51                        | 200                          | 145                      | 0                       | 3            | 0.12          | 0              | 1              | 15               |
| 22   | 7         | 4.25           | 72                          | 15.61                       | 8.46| 7.1           | 120.76                        | 200                          | 74                       | 36                      | 3            | 0.12          | 0              | 4              | 14               |
| 23   | 20        | 3.51           | 201                         | 19.81                       | 8.00| 21.3          | 150.31                        | 200                          | 166                      | 97                      | 4            | 0.12          | 0.4            | 14             | 16               |
Climatological and Cultural Influences on Annual Groundwater Decline in the Mississippi Delta Shallow Alluvial Aquifer: Identifying the Causes and Solutions

Basic Information

<table>
<thead>
<tr>
<th>Title:</th>
<th>Climatological and Cultural Influences on Annual Groundwater Decline in the Mississippi Delta Shallow Alluvial Aquifer: Identifying the Causes and Solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Number:</td>
<td>2007MS63B</td>
</tr>
<tr>
<td>Start Date:</td>
<td>3/1/2007</td>
</tr>
<tr>
<td>End Date:</td>
<td>8/31/2008</td>
</tr>
<tr>
<td>Funding Source:</td>
<td>104B</td>
</tr>
<tr>
<td>Congressional District:</td>
<td>3rd</td>
</tr>
<tr>
<td>Research Category:</td>
<td>Climate and Hydrologic Processes</td>
</tr>
<tr>
<td>Focus Category:</td>
<td>Climatological Processes, Groundwater, Water Use</td>
</tr>
<tr>
<td>Descriptors:</td>
<td></td>
</tr>
<tr>
<td>Principal Investigators:</td>
<td>Charles Wax, Jonathan Woodrome Pote</td>
</tr>
</tbody>
</table>

Publication

The shallow alluvial aquifer is the main source of groundwater developed in the Mississippi Delta region. The aquifer is heavily used for irrigation of corn, soybeans, and cotton, as well as for rice flooding and filling aquaculture ponds in the prominent catfish industry. Water levels in the aquifer are subject to seasonal declines and annual fluctuations caused by both climatological and crop water use variations from year-to-year. These declines can be dramatic and are most notable during the period April-October of each year, particularly in years when normal crop water demands are accentuated by concurrent abnormally dry climatic conditions. Recharge during the remainder of the year has recently been insufficient to restore water levels, and the aquifer is now being mined at the approximate rate of 300,000 acre-feet per year. To underscore the critical nature of this water problem, the most recent water level decline in the aquifer (October 2005-2006) is estimated at 500,000 acre-feet (Pennington, 2006). This may represent a worst-case situation in which severe drought combined with consequent increased demand for irrigation. It is estimated that water use for row crops doubled during this period (Pennington, 2006).
It is of critical importance to understand how climatological variability and cultural uses of the water cause the groundwater level in the aquifer to vary. It is also critical to discover and implement management strategies to use precipitation and other surface water sources as substitutes for aquifer withdrawals and thereby reduce the use of groundwater in the region. Stopping the consistent drop in water level in the aquifer will require a curtailment of about 300,000 acre-feet of groundwater use each year, and this is the highest priority of this research project. This information is essential to agricultural producers in the region and to planners in the Yazoo Water Management District who must design sustainable water use scenarios which will allow continuation of the productivity of the region.

10. Statement of the results, benefits, and/or information expected to be gained from this study:

Relationships between use and water level drop in the aquifer will be the chief result of this study. Baseline information on maximum decline during drought will be compiled, with the assumption that these times of decline are unavoidable. Alternatives to mitigate the declines of water levels in other years will include strategies to optimize use of surface water and captured precipitation in lieu of groundwater.


The purpose of this research is to determine causes of short-term aquifer declines, primarily cultural water uses and climatological processes, with a conscious effort to exclude the effects of river recharge or extraction. The spatial scope of the research is the central part of the Delta, the temporal scope is a period from 1980-2006. Primary objectives are to assess the effects of agricultural demands/uses and climatological variability on withdrawal of water from the shallow alluvial aquifer. The main concern is to evaluate the long-term drop in water level in the aquifer, stemming from growing season uses exceeding recharge rate year-after-year. The approach to be taken is to determine what each year’s annual decline has contributed to the multi-year decline.

The “sawtooth” pattern presently identified is one in which declines in the water level occur seasonally during wet years with mostly complete recovery, but the decline during drought years is much more substantial and recovery is negligible. Over the past 30 years this has resulted in an overall decline in water level in the aquifer. There is little that can be done to reduce the water demand of agriculture in dry years, but in years with at least normal or above normal rainfall, maximizing use of that rain to substitute for groundwater is a preferred alternative. Once the size of the demand is known, the research will attempt to determine alternatives needed to offset the demand. Since drought years will inevitably cause groundwater level decline, in years of normal or surplus rainfall the precipitation must be used to make up any declines in water level from cultural uses. The nature of this research is to determine if the amount of precipitation used in lieu of groundwater in wet years can be sufficient to offset the combined decline of both that year and drought years.

12. Methods, procedures, and facilities. Provide enough information to permit evaluation of the technical adequacy of the approach to satisfy the objectives.
The initial phase of the research will involve collecting the climate record, the water level record, and the water use record for major users of groundwater in a centrally-defined portion of the region. Climatological data will be used to establish drought years. The water level record and water use records will be used to establish a maximum demand water use, which will be referenced to the amount of acreages of various crops using water in those drought years. There will also be an attempt to reference water use to changing practices over time. For example, catfish farming no longer uses pond flushing, rice culture no longer produces tail-water, etc., thus water use totals will have to be time-indexed to the acceptable practices of different years. These procedures will produce an evaluation of overuse periods and amounts, maximum sustainable use, and required savings in water use to eliminate or mitigate water level decline in the aquifer.

Present best management practices will be assessed to see if they can, over a period of years, reduce use enough to stop water level declines. Specific practices to be evaluated include those that are designed to collect and store rainfall for use in place of pumped groundwater. Examples include the 6/3 management strategy in catfish pond, and a similar strategy in rice fields which similarly relies on leaving storage capacity inside the levees of rice fields instead of keeping the fields completely covered all the time. Specific methods are 1) statistically correlate groundwater drop with climatic variability and cultural water use in drought years, wet years, and average years; 2) statistically correlate recharge rates in those same years; and 3) determine the net demand during each of those years. Then the potential amount of captured precipitation with the various management strategies will be applied against these previously determined demands.

Existing climate data will be used, and the cooperator on this project—the Yazoo Mississippi Delta Joint Water Management District—will supply the needed water level and cultural water use information for analysis (see attached cooperator letter). Additional equipment purchases are not anticipated from this funding.

13. Related Research. Show by literature and communication citations the similarities and dissimilarities of the proposed project to completed or on-going research on the same topic.

Agriculture is the major water consumer in the southeast region, and aquaculture has the potential to become disproportionately consumptive. For example, most row crops in the region require 30-40 cm/yr, whereas catfish farming requires up to 100 cm/yr under current practices. In the “Delta” region of Mississippi where nearly 60% of U.S. farm raised catfish are produced, catfish production accounts for about 28% of all water used (Pennington, 2005). Research to reduce reliance on groundwater in aquaculture has shown remarkable potential reductions in groundwater use by use of management strategies to create storage capacity which can capture rainfall to keep ponds filled. For example, one study shows the potential to reduce consumption of groundwater in delta catfish ponds by precipitation capture by nearly 70% annually (Pote and Wax, 1993; Pote, et al, 1988; Cathcart et al., 2006). Extension Services in Alabama and Louisiana include variations of those strategies as industry best management practices for reducing groundwater use in those states (Auburn University, 2002; LCES, 2003). In rice production, straight levee systems and use of multiple inlets have been shown to significantly reduce water use (Smith et al., 2006). Intermittent (wet-dry) irrigation has been shown to reduce water use and NPRS runoff by up to 50% with no yield losses in Mississippi field trials (Massey et al., 2006).


Pennington, Dean, 2005. 2005 Annual Report, Yazoo Mississippi Delta Joint Water Management District, Stoneville, MS 38766.

Pennington, Dean, 2006. Personal communication, October 31, 2006.


14. Investigator's qualifications. Include a resume(s) of the principal investigator(s). No resume shall exceed two pages or list more than 15 pertinent publications.

Biosketches are appended.

15. Training potential. Estimate the number and level of graduate and undergraduate students, by field of study and degree that are expected to receive training in the project.

One graduate and two undergraduate students will be supported by these funds. It is anticipated that additional students will contribute to the research. Those students supported by this project are geoscience students, working toward B.S. and M.S. degrees.
Identify the Information Transfer Plan (up to two pages). Indicate the plan for disseminating information on the results of the research and promoting their application.

1. Define the subject matter and the problems to be addressed.

   This research addresses declining water levels in the shallow alluvial aquifer in the Mississippi Delta region. Potential causes and alternative water management strategies to stabilize the aquifer are identified.

2. Identify the target audience.

   The target audience includes water users in the Mississippi Delta region (agriculture, aquaculture) and water managers (YMD Joint Water Management District, US Army Corps of Engineers). In addition, scientists doing similar research will be targeted.

3. Indicate the strategies to be employed; e.g. workshops, publications.

   Results will be published in both MAFES Bulletin format and journal articles. Results will be presented at the annual Mississippi Water Resources Conferences and published in the Proceedings of that conference. Results will be specifically shared with NRCS and MDEQ personnel involved in water management in the region.

4. Identify the cooperators (e.g., Cooperative Extension service).

   The primary cooperator is the Yazoo Mississippi Delta Joint Water Management District. Cooperators on information transfer specifically are identified above.
Budget. Submit a detailed budget for each project. Indicate the amount of cost sharing for each element:

<table>
<thead>
<tr>
<th>Cost Category</th>
<th>Federal $</th>
<th>State $</th>
<th>3rd party $</th>
<th>Total $</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Salaries and Wages</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PI Wax</td>
<td>93,537</td>
<td>4,677</td>
<td>4,677</td>
<td>9,354</td>
</tr>
<tr>
<td>Co-I Pote</td>
<td>112,723</td>
<td>1,691</td>
<td>1,691</td>
<td>3,382</td>
</tr>
<tr>
<td>Co-I Massey</td>
<td>79,327</td>
<td>1,983</td>
<td>1,983</td>
<td>3,966</td>
</tr>
<tr>
<td>GRA</td>
<td>15,000</td>
<td>3,750</td>
<td>3,750</td>
<td>7,500</td>
</tr>
<tr>
<td>Student 200 hrs</td>
<td>800</td>
<td>800</td>
<td>0</td>
<td>1,600</td>
</tr>
<tr>
<td>Total</td>
<td>12,901</td>
<td>12,901</td>
<td>0</td>
<td>25,802</td>
</tr>
<tr>
<td>2. Fringe Benefits</td>
<td>3,701</td>
<td>3,701</td>
<td>0</td>
<td>7,402</td>
</tr>
<tr>
<td>3. Supplies</td>
<td>2,000</td>
<td>2,000</td>
<td>0</td>
<td>4,000</td>
</tr>
<tr>
<td>4. Permanent Equipment</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5. Travel</td>
<td>1,000</td>
<td>1,000</td>
<td>0</td>
<td>2,000</td>
</tr>
<tr>
<td>6. Other Direct Costs</td>
<td>0</td>
<td>0</td>
<td>60,000</td>
<td>60,000</td>
</tr>
<tr>
<td>7. Total Direct Costs</td>
<td>19,602</td>
<td>19,602</td>
<td>60,000</td>
<td>99,204</td>
</tr>
<tr>
<td>8. Indirect Costs</td>
<td>0</td>
<td>15,926</td>
<td>0</td>
<td>15,926</td>
</tr>
<tr>
<td>9. Total Estimated Costs</td>
<td>19,602</td>
<td>35,528</td>
<td>60,000</td>
<td>115,130</td>
</tr>
</tbody>
</table>
Charles Wax,

This letter is submitted as evidence of the YMD Joint Water Management District’s interest in supporting your proposed project “Climatological and Cultural Influences on Annual Groundwater Decline in the Mississippi Delta Shallow Alluvial Aquifer: Identifying Causes and Solutions”

YMD is will support your project financially by contributing YMD resources through staff time and travel to monitor water level changes in the Alluvial aquifer, calculate semi-annual changes in the water stored in the Aquifer, and measuring typical water use for the irrigation of the major Delta crops. The value of the YMD contribution is estimated to be $60,000.

Dean Pennington
YMD Joint Water Management District
Stoneville, MS
Bio-Sketch: Charles L. Wax

Experience:
Professor of Geography, Mississippi State University, 1987-present;
Professor and Head of the Department of Geosciences, Mississippi State University, 1989-2001;
State Climatologist for Mississippi, 1983-present;
Part-time Professor of Geography, Mississippi University for Women, 1985-1987;
Research Climatologist, Miss. Ag. and Forestry Experiment Station, Dept. of Ag. and
Bio. Engineering, Mississippi State University, part-time 1984-1990;
Associate Professor of Geography, Mississippi State University, 1983-1987;
Assistant Professor of Geography, Mississippi State University, 1978-1983;
Associate Scientist, Coastal Environments, Inc., Baton Rouge, LA, 1977;
Graduate Research Assistant, Center for Wetland Resources, LSU, 1975-1977;
Research Associate, Coastal Studies Institute, LSU, summer 1973;
Instructor, Department of Geography and Anthropology, LSU, 1973-1975;

Education:
Ph.D. (physical geography: climatology), Louisiana State University, 1977
M.S. (physical geography: geomorphology), Louisiana State University, 1974
B.A. (political science), Delta State University, 1969
A.A., Miss. Delta Jr. College, 1967

Specialties:
Physical geography, applied climatology, meteorology, water resources, natural resource conservation

Courses Taught:
World Geography                                       Physical Geography
Meteorology                                           Meteorology I: Observations
Synoptic Meteorology                                  Conservation of Natural Resources
Geography of North America                            Geowriting
Climatology                                           Special Topics in Geography
Applied Climatology                                   Hydroclimatology
Geography of Mississippi                              Field Methods in Geography
Computer Applications in Geosciences                  Geographic Literature
Geographic Seminar                                    Directed Individual Studies in Geography

Honors/Awards/Offices Held:
Charles L. Wax is active in several state, regional, and national organizations, among which are the Mississippi Geographic Alliance and the Association of American Geographers. He served on and chaired the U.S.D.A.'s Southern Region Research Committee for Climatology in Agricultural Production, and has served as President of the American Association of State Climatologists. He has been presented the Outstanding Faculty Award by the University Honors Council at Mississippi State University.

Presentations and Publications:
Authored or co-authored 82 publications on climatological, water resources, and environmental topics
Presented 53 papers at professional meetings—examples:


1996. ______. "Geography of Mississippi." In Microsoft Encarta 96 Encyclopedia. Microsoft Corporation, Redmond, WA.


2006. ______. “Climate of Mississippi.” Climatology of The United States No. 60, National Oceanic and Atmospheric Administration, National Climatic Data Center, Asheville, NC. Online at: http://www5.ncdc.noaa.gov climatenormals clim60 states Clim_MS_01.pdf
Joseph Harry Massey

Vitae

Dr. Massey is an associate professor/pesticide scientist (20% teaching, 80% research) with Mississippi State University in Starkville. He teaches graduate-level courses in *Herbicide Physiology & Biochemistry* (PSS 8724) and the *Environmental Fate of Herbicides* (PSS 8634). As coordinator of the Environmental Science minor/certificate program at MSU, he also teaches *Introduction to Environmental Science* (ENS 2102) for undergraduates. His research investigates water quality/quantity issues in agriculture.

Education

**B.S. Chemistry/Mathematics minor, 1986. University of Central Arkansas, Conway.**

Professional Experience

**Associate Professor**, Department of Plant and Soil Science, Mississippi State University, Starkville. *July 2005 to present.*  
**Assistant Professor**, Department of Plant and Soil Science, Mississippi State University, Starkville. *January 2000 through June 2005.*  
**Section Research Chemist**, Regulatory E-Fate Field Group, DuPont Crop Protection, Newark, DE. *July 1997 through November 1999.*  
**Research Chemist**, Regulatory E-Fate Laboratory Group, DuPont Crop Protection, Newark, DE. *August 1995 through July 1997.*  
**Laboratory Instructor**, Department of Chemistry & Biochemistry, University of Delaware, Newark, DE. *Fall 1996 and 1997; Spring 1998.*  
**Research Assistant**, Pesticide Residue Laboratory, University of Arkansas, Fayetteville, AR. *May 1989 through July 1995.*  
**Graduate Assistant**, Pesticide Residue Laboratory, University of Arkansas, Fayetteville, AR. *August 1986 through April 1989.*  
**Chemist Intern**, Water Laboratory, Arkansas Department of Environmental Quality, Little Rock, AR. *June through August 1986.*

Recent Publications


**External Funding (2000-2006): $1,399,421**

**Membership**, American Chemical Society; American Society of Agronomy & Soil Science Society of America; American Association for the Advancement of Science; Weed Science Society of America
JONATHAN W. POTE

Contact: 204 Howell Engineering
          PO Box 5465
          State, MS 39762; (662)325-3282

Date and Place of Birth: March 3, 1953; Seligman, Arizona

Education:
Ph.D., Engineering, 1984, University of Arkansas, Fayetteville, Arkansas
M.S., Civil Engineering, 1979, Oregon State University, Corvallis, Oregon
B.S., Chemistry, 1975, Hendrix College, Conway, Arkansas.

Employment: Associate Director, Mississippi Agricultural and Forestry Experiment Station, Mississippi State University, 2006 to present; Professor, Biological Engineering, Mississippi State University, 1994 to present; Interim Vice President for Research, Mississippi State University, 2002 to 2004; Associate Vice President for Research, Mississippi State University, 1998 to 2002; Director, Water Resources Research Institute, Mississippi State University, 1992 to 1998; Associate Professor, Biological Engineering, Mississippi State University, 1989 to 1994; Assistant Professor, Biological Engineering, Mississippi State University, 1985 to 1989; Peace Corps Volunteer, Corozal Town, Belize, Central America, 1975 to 1977.

Research Areas: Water chemistry, water quality, water management and conservation, aquaculture, environmental planning.

Professional Societies: National Association of State Universities and Land Grant Colleges, Chair, Section on Water Resources, 2000; Chair, Division of Natural Resources, 2002; National Institutes of Water Resources; President, 1998-1999; Director, South Atlantic Gulf Region; Lead Institute, Southeast and Island Region; Board of Directors; Universities Council on Water Resources; President, 2000 – 2001; Chair, Policy, Legislation, and Administration Committee; Board of Directors; American Society of Agricultural Engineers, Member; Gamma Sigma Delta, Member; Sigma Xi, Member.

Funded Grants: Total over $20,000,000; Sources: National Science Foundation, Environmental Protection Agency, Department of Energy; US Geological Survey, US Department of Agriculture, Department of Interior.

Select Publications:


A Continuation of Climatological and Cultural Influences on Annual Groundwater Decline in the Mississippi Delta Shallow Alluvial Aquifer: Modeling Potential Solutions (Year Two)

Basic Information

<table>
<thead>
<tr>
<th>Title:</th>
<th>A Continuation of Climatological and Cultural Influences on Annual Groundwater Decline in the Mississippi Delta Shallow Alluvial Aquifer: Modeling Potential Solutions (Year Two)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Number:</td>
<td>2008MS72B</td>
</tr>
<tr>
<td>Start Date:</td>
<td>3/1/2008</td>
</tr>
<tr>
<td>End Date:</td>
<td>2/28/2009</td>
</tr>
<tr>
<td>Funding Source:</td>
<td>104B</td>
</tr>
<tr>
<td>Congressional District:</td>
<td>3rd</td>
</tr>
<tr>
<td>Research Category:</td>
<td>Climate and Hydrologic Processes</td>
</tr>
<tr>
<td>Focus Category:</td>
<td>Climatological Processes, Groundwater, Water Use</td>
</tr>
<tr>
<td>Descriptors:</td>
<td>None</td>
</tr>
<tr>
<td>Principal Investigators:</td>
<td>Charles Wax, Joseph H. Massey, Jonathan Woodrome Pote</td>
</tr>
</tbody>
</table>

Publication

Mississippi Water Resources Research Institute (MWRRI)

Final Technical Report – (From) 03/01/08 – (To) 02/28/09

Project Title: A continuation of climatological and cultural influences on annual
groundwater decline in the Mississippi Delta shallow alluvial aquifer:
Modeling potential solutions (year two) (fund #330912/830912)

Principal Investigator: Charles L. Wax, PI (co-PI Jonathan Pote, Joe Massey)

Institution: Department of geosciences, Mississippi State University
Address: P.O. Box 5448, Mississippi State, MS 39762
Phone/Fax: (662) 325-3915
E-Mail: wax@geosci.msstate.edu

Approximate expenditures during reporting period:

Federal: $18,304  Non-Federal: $40,000 (in-kind) Cost Share: $16,973

Equipment purchased during reporting period: none

Research completed:

Water use from the delta aquifer, contributed as in-kind contribution to the project
by the Yazoo-Mississippi Delta Joint Water Management District, has been quantified by
crop, acreage, and irrigation method. A relationship between growing season rainfall
and irrigation water use has been developed to link interannual variations in water use to
variations in climate (rainfall). Water use coefficients have been developed to link each
specific type of irrigation on each crop type with a water use amount in acre feet per
acre. A complete prototype water use model has been completed using acreages,
irrigation methods, and management strategies in place during 2006 in Sunflower
County to predict annual water demand for cotton, rice, soybeans, corn, and catfish.
Figure 1 shows the inputs and the resulting estimate of annual water use for Sunflower
County. The model is constructed in an Excel spreadsheet. The interactive model file is
sent as a separate file along with this report.
Figure 1. Model illustration

The growing season climate data for the last 47-years were used to run the water demand model for a 47-year (2008-2055) period into the future to assess aquifer drawdown and recharge characteristics annually and cumulatively over the long-term period. Changes in acreages of the major crops, specific irrigation methods, and water management strategies were used to create various scenarios, then conduct multiple model runs to assess the effects of the instituted changes on aquifer drawdown and recharge characteristics over the long-term period.

Four scenarios were simulated with the model. The simulations and results are as follows:

The static 2006 scenario

The Static 2006 scenario reflected what the state of aquifer would be if no changes were made in the climate or cultural land uses or practices throughout the period. All crop acreages, irrigation methods, and percentages of irrigation methods remained the same as documented in 2006. As shown in Figure 2, during the first ten years, water volumes in the aquifer slowly declined. This occurred because growing season precipitation was below normal during these years causing the demand for irrigation to rise; therefore, in those years, withdrawals exceeded recharge. For the next approximately 30 years, the volume of the aquifer reached a stationary level. This can be attributed to two factors. First, there are a number of years during this period that growing season precipitation far exceeds the average, allowing for greater recharge to occur. Secondly, managers at YMD began to make conservation efforts, and believe that the results of those efforts are evident in the rebounding water levels. In the last seven years, there is again a marked decline. This could be attributed to the fact that there were a number of drought years during the period, and the amount of precipitation received was not sufficient to sustain levels due to withdrawals for irrigation.
Most Conservative Irrigation Methods Implemented Scenario

The most conservative irrigation method for each crop was used to determine the effects water conservation efforts could have on the aquifer for the 47 year period. In this scenario, the most conservative method for each crop was the only method used for irrigation. For example, 100% of cotton irrigation was assigned to center-pivot irrigation, and all other methods of irrigation of cotton were assigned a value of 0. All other irrigation methods for the conservative and consumptive scenarios are shown in Table 1. Figure 3 shows the difference between the static 2006 “base” model (blue) and the state of the aquifer after the conservation changes were made (red). The result is an increase of approximately 3,000,000 acre-feet of water in the aquifer over the entire period, with a consistent increase in water volume throughout time as recharge overcame withdrawal year after year.

Table 1. Irrigation methods used in conservative and consumptive scenarios

<table>
<thead>
<tr>
<th>Crop</th>
<th>Irrigation Method</th>
<th>Conservative</th>
<th>Consumptive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cotton</td>
<td>pivot</td>
<td></td>
<td>furrow</td>
</tr>
<tr>
<td>Rice</td>
<td>zero-grade</td>
<td></td>
<td>contour</td>
</tr>
<tr>
<td>Corn</td>
<td>pivot</td>
<td></td>
<td>straight</td>
</tr>
<tr>
<td>Soybeans</td>
<td>zero-grade</td>
<td></td>
<td>pivot</td>
</tr>
<tr>
<td>Catfish</td>
<td>6/3</td>
<td></td>
<td>MF</td>
</tr>
</tbody>
</table>
Most Consumptive Irrigation Methods Implemented Scenario

This scenario is the opposite of the previous scenario and represents a situation in which the most consumptive irrigation method is implemented. This particular scenario and its resulting output would be a good example to use when conveying to farmers, producers, other water consumers, and planners the need for conservation practices. As shown in Figure 4, if the most consumptive irrigation method was used for each crop, the aquifer would lose approximately 30,000,000 acre-feet of water over the 47-year period by experiencing a consistent annual loss of water volume as more water was withdrawn than recharge could replace. It is not known at what point the aquifer would be completely de-watered.
Use of surface water scenario

A GIS analysis was performed to determine the number of acres within one-quarter mile of all streams in the Delta. The technique was used to map all streams in the Delta, then place a quarter mile buffer around each stream, then calculate the total number of acres in the buffer zones. The number found was about 25% of the total acres in the Delta, so it was assumed that about 25% of irrigated acres could potentially be irrigated with surface water when it was available. It was then assumed that surface water would be available in the streams when growing season precipitation was 30% or more above average. The model was then set to allow for 25% of total irrigation from surface water in place of groundwater in those years. The model then calculated savings in groundwater use by assuming surface water was used for irrigation on 25% of the acres when available through the 54-year period (Figure 5).
Problems Encountered:
Identifying controls of aquifer recharge rates has not been successful. Attempts to relate recharge to Mississippi River stage on the west, to Grenada Lake stage on the east, and to non-growing season precipitation totals on both east and west sides of the delta have not been successful. Annual recharge used in the model scenarios was the average of the 19 years of measured recharge supplied by YMD. Changes in cultural practices adopted for the various model run scenarios are not known to be practical or economically feasible—these need to be confirmed as valid possibilities before rigid recommendations are developed. An attempt to make the model represent total water use across the entire delta region (not just Sunflower County) was not successful. All acreages of the five crop types were collected, but irrigated acreages were not available for all the counties. Using the percentages of irrigated to non-irrigated acres measured for Sunflower County was not considered accurate after several unsuccessful attempts to estimate total delta-wide water use.

Publications/Presentations
1. Presentation of preliminary results to Mississippi Department of Environmental Quality, June 2008.

2. Presentation of preliminary results to Yazoo-Mississippi Delta Joint Water Management District, DEQ, and USGS special committee on delta groundwater modeling, Stoneville, February 2009. (Power Point slides sent as separate file along with this report)

3. Tia L. Merrell, 2008. Development of an Interactive Model Predicting Climatological and Cultural Influences on Annual Groundwater Volume in the Mississippi Delta Shallow Alluvial Aquifer. A thesis submitted to the faculty of the department of geosciences, Mississippi State University. (Word file sent as a separate attachment with this report)
### Student Training:

<table>
<thead>
<tr>
<th>Name</th>
<th>Level</th>
<th>Thesis</th>
<th>Major</th>
<th>Graduation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tia L. Merrell</td>
<td>M.S.</td>
<td>Yes</td>
<td>Geosciences</td>
<td>May 2009</td>
</tr>
<tr>
<td>Victoria Lemmermann</td>
<td>B.S.</td>
<td>No</td>
<td>Geosciences</td>
<td>May 2010</td>
</tr>
</tbody>
</table>

Report submitted by:  
Charles L. Wax  
March 2, 2009
DEVELOPMENT OF AN INTERACTIVE MODEL PREDICTING CLIMATOLOGICAL AND CULTURAL INFLUENCES ON ANNUAL GROUNDWATER VOLUME IN THE MISSISSIPPI DELTA SHALLOW ALLUVIAL AQUIFER

Problem

- Alluvial aquifer experiencing approximately 300,000 acre-feet per year decline due to the continuous drought and subsequent demand for irrigation

Objectives

- Quantify both natural climatological variation and cultural water use
- Utilize that information to construct a simulation model that can be used to recommend strategies to retard the rate of drawdown in the aquifer

Study Area

- Study area of well-monitoring system as defined by Yazoo Mississippi Delta Joint Water Management District (YMJD)
- Sunflower County at center of greatest drawdown

Model Variables

- Climatological
  - Growing season precipitation
    - May—August
- Cultural
  - Crop type
    - Cotton, corn, rice, soybeans, catfish
  - Irrigation methods
    - Furrow, straight-levee, contour-levee, zero-grade, multiple-inter, center pivot, maintain fall, 5/3
  - Water Use
    - Supplied by YMJD in acre-feet per acre (A-FA)

Growing Season Precipitation

- Moorhead, MS
  - Located centrally in Sunflower County
Specific Irrigation Methods
- Six irrigation methods used in this study
  - Row crop and rice
  - Two aquaculture management methods
  - Yellow—advantage
  - Red—disadvantage

Furrow Irrigation
- Least expensive method
- Water-consumptive

Contour-Levee (CL) Irrigation
- Follows natural slope of field
- Water-consumptive

Straight-Levee (SL) Irrigation
- Requires fewer levees than CL
- Typically 25% savings over CL
- Requires mechanical equipment

Zero-Grade (ZG) Irrigation
- No levees needed
- Typically 20% savings over SL
- Limited to small fields

Center Pivot (CP) Irrigation
- Low labor requirements
- Uniform application of water
- High initial cost
Multiple Inlet (MI) Irrigation

- Reduction in runoff and pumping costs
- Low labor costs
- Initial cost of installation
- Working around tubing

Development of Rain-Irrigation Relationship

- Variables
  - Growing season precipitation (X)
  - Groundwater used for irrigation (Y)

Regression Input: Precipitation (x) vs. Total Average Water Use (y)

<table>
<thead>
<tr>
<th>Year</th>
<th>GSP</th>
<th>Cotton</th>
<th>Rice</th>
<th>Corn</th>
<th>Soybeans</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>11.19</td>
<td>0.54</td>
<td>3.15</td>
<td>0.93</td>
<td>0.68</td>
</tr>
<tr>
<td>2003</td>
<td>14.84</td>
<td>0.47</td>
<td>2.76</td>
<td>0.58</td>
<td>0.64</td>
</tr>
<tr>
<td>2004</td>
<td>23.63</td>
<td>0.34</td>
<td>2.45</td>
<td>0.42</td>
<td>0.47</td>
</tr>
<tr>
<td>2005</td>
<td>15.22</td>
<td>0.51</td>
<td>2.97</td>
<td>0.96</td>
<td>0.60</td>
</tr>
<tr>
<td>2006</td>
<td>7.28</td>
<td>0.84</td>
<td>3.34</td>
<td>1.16</td>
<td>1.00</td>
</tr>
<tr>
<td>2007</td>
<td>15.53</td>
<td>0.50</td>
<td>3.00</td>
<td>0.80</td>
<td>0.80</td>
</tr>
</tbody>
</table>

Cotton Example

\[ y = -0.03x + 0.93, \quad R^2 = 0.80 \]

Development of Irrigation Coefficients (Cotton Example)

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Avg (A-F/A)</th>
<th>Furrow (A-F/A)</th>
<th>Pivot (A-F/A)</th>
<th>Furrow to Avg (A-F/A)</th>
<th>Pivot to Avg (A-F/A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>0.56</td>
<td>0.53</td>
<td>0.50</td>
<td>1.06</td>
<td>0.80</td>
</tr>
<tr>
<td>2006</td>
<td>0.84</td>
<td>0.89</td>
<td>0.62</td>
<td>1.06</td>
<td>0.74</td>
</tr>
<tr>
<td>2005</td>
<td>0.51</td>
<td>0.55</td>
<td>0.42</td>
<td>1.08</td>
<td>0.82</td>
</tr>
</tbody>
</table>

\[ 0.53 \text{ A-F/A} = 1.06 \quad 0.40 \text{ A-F/A} = 0.80 \]

\[ 0.50 \text{ A-F/A} \]

\[ (1.06 + 1.06 + 1.08)/3 = 1.07 \quad (0.80 + 0.74 + 0.82)/3 = 0.79 \]

Rainfall-irrigation relationship gives average water use for each crop

Model then calculates water used by each specific irrigation method for each crop (irrigation coefficient)
Development of the Model

<table>
<thead>
<tr>
<th>Column</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
</tr>
</thead>
<tbody>
<tr>
<td>DELTA MODEL-Sunflower County 1981-2006</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>GS Precip</td>
</tr>
<tr>
<td>2</td>
<td>1981/2000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Total Acres</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>COTTON</td>
<td>% furrow</td>
<td>% pivot</td>
<td></td>
<td></td>
<td></td>
<td>16.73</td>
</tr>
<tr>
<td>5</td>
<td>60000</td>
<td>0.61</td>
<td>0.19</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>RICE</td>
<td>% contour</td>
<td>% straight</td>
<td>% ML</td>
<td>% ZG</td>
<td></td>
<td>16.73</td>
</tr>
<tr>
<td>7</td>
<td>27000</td>
<td>0.2</td>
<td>0.56</td>
<td>0.12</td>
<td>0.12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>CORN</td>
<td>% furrow</td>
<td>% pivot</td>
<td>% Str</td>
<td>% ZG</td>
<td></td>
<td>16.73</td>
</tr>
<tr>
<td>9</td>
<td>6910</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>16.73</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>SOYBEANS</td>
<td>% furrow</td>
<td>% straight</td>
<td>% pivot</td>
<td>% contour</td>
<td>% ZG</td>
<td>16.73</td>
</tr>
<tr>
<td>11</td>
<td>96350</td>
<td>0.49</td>
<td>0.4</td>
<td>0.03</td>
<td>0.06</td>
<td>0.02</td>
<td>16.73</td>
</tr>
<tr>
<td>12</td>
<td>CATFISH</td>
<td>% MF</td>
<td>% B/R</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>24000</td>
<td>0.37</td>
<td>0.63</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Model Simulation Scenarios

- Several scenarios conducted to determine:
  - Various effects changes would have on overall water use
  - Sensitivity to changes in specific crop acreages and irrigation methods

Static 2006 Scenario

Most Conservative Irrigation Methods Implemented Scenario

Most Consumptive Irrigation Methods Implemented Scenario
Addition of Surface Water Scenario

- Total Area of Delta: 4,480,000 acres
- Total Area of Streams Buffer: 1,102,647 acres
- ~25% of Total Delta Area

Practical Applications

- Permitting
- Climatological Scenarios

Permitting

- ~15,000 wells currently in operation in the Delta
- Over 80% of all water use permits for MS are in the Delta

Adoption of New Permitting Procedures

- Adopted as a result of confidence in model simulations (!!!)
- New Changes
  - Applicant must meet specified water conservation requirements to receive 10 year Class 1 permit
  - If requirements not met, will receive 3 year, Class 2 permit
  - At end of 3 years, subject to investigation

Climatological Scenarios

- Climate variability
  - If Delta received 20-30% more/less rainfall
  - Number of drought years followed by rainy years
- Senate Bill 2860
  - MS Global Climate Study Commission
  - Use model in this study
Limitations
- Assumption that growing season precipitation totals are sufficient
- Water use survey sites not entirely representative of irrigation methods used throughout Delta
- Finite water volume of aquifer is unknown

Conclusions
- Model is a sensitive tool useful for various forms of analysis
  - User-friendly and completely interactive
- Can be used to recommend water use management techniques
- Can be used to simulate various scenarios including climate change

Further Research
- Expand model to reflect entire Delta region
- Continued updates and improvements to model as more measured water use data become available
Multi-scale Evaluation and Analysis of Precipitation Patterns over the Mississippi Delta

Basic Information

<table>
<thead>
<tr>
<th><strong>Title</strong></th>
<th>Multi-scale Evaluation and Analysis of Precipitation Patterns over the Mississippi Delta</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Project Number</strong></td>
<td>2008MS73B</td>
</tr>
<tr>
<td><strong>Start Date</strong></td>
<td>3/1/2008</td>
</tr>
<tr>
<td><strong>End Date</strong></td>
<td>2/28/2009</td>
</tr>
<tr>
<td><strong>Funding Source</strong></td>
<td>104B</td>
</tr>
<tr>
<td><strong>Congressional District</strong></td>
<td>3rd</td>
</tr>
<tr>
<td><strong>Research Category</strong></td>
<td>Climate and Hydrologic Processes</td>
</tr>
<tr>
<td><strong>Focus Category</strong></td>
<td>Water Quality, Climatological Processes, Hydrology</td>
</tr>
<tr>
<td><strong>Descriptors</strong></td>
<td>None</td>
</tr>
<tr>
<td><strong>Principal Investigators</strong></td>
<td>Jamie Dyer</td>
</tr>
</tbody>
</table>

Publication

Multi-scale Evaluation and Analysis of Precipitation Patterns over the Mississippi Delta

Jamie Dyer, Ph.D.

Mississippi State University
Department of Geosciences
P.O. Box 5448
Mississippi State, MS 39762-5448

jamie.dyer@msstate.edu

Keywords:
- Watershed management, Water resources development

Duration:
- March 2008 – February 2009

Federal funds requested:
- $12,658

Non-federal funds pledged:
- State funds -- $11,737
- Coop contribution -- $20,000
Abstract

The Mississippi River floodplain in northwestern Mississippi, often referred to as the Mississippi Delta, is extremely important for regional economic stability and growth due to the widespread agriculture in the area. The region is unique in that there are currently three sources of precipitation measurements available: (1) radar-derived precipitation estimates from National Weather Service (NWS) NEXRAD network, surface observations from NWS recording stations, and surface observations from US Department of Agriculture (USDA) Soil Climate Analysis Network (SCAN) recording stations. In terms of water resource management and climatological precipitation research, quantitatively defining the biases associated with available precipitation data sources is critical in choosing which source to use for a given application. Additionally, due to the importance of precipitation in agriculture along with recent drought in the Mississippi Delta region, precipitation patterns should be reevaluated in terms of duration frequency, and extent. The inclusion of long-term data from surface gages along with shorter-term but higher resolution radar-derived rainfall estimates allow for a detailed analysis of past and current precipitation trends. This will lead to a better understanding of rainfall trends and patterns and potentially better prediction of future rainfall.
1. Project Overview

The Mississippi River floodplain in northwestern Mississippi, eastern Arkansas, and northeastern Louisiana is a key agricultural region in the southern United States. Often referred to as the Mississippi Delta, despite being an alluvial plain, the region is characterized by extremely deep, rich soils deposited through repeated flooding of the Mississippi River over the past millennia. The area is so conducive to crop production that 80% of Mississippi's agricultural products originate in the Delta region (Delta Council, 2005), which is considerable since Mississippi alone is the third largest producer of cotton and fourth largest producer of rice in the United States. In addition, agriculture in the Mississippi Delta comprises roughly 33% of Mississippi's total cash receipts; therefore, both local and state economies are highly dependent on agricultural production and stability. The same is true for Arkansas, where the Mississippi Delta is the primary agricultural center of the state.

Agriculture is known to be highly dependent on climatological variables related to the surface energy and water budgets, namely temperature and precipitation. Surface temperature (and the associated solar radiation flux) drives the photosynthetic process, leading to biomass increase and fruit production, while precipitation is necessary to maintain soil moisture for transpiration and latent heat fluxes from the surface. As a result, knowledge of the patterns of these climatological variables over monthly, seasonal, and annual scales is crucial in determining near- and long-term agricultural sustainability. This is especially true in light of possible climate change scenarios, in which the surface energy and water balances may be modified through global warming. This can have far reaching consequences on agricultural (Adams et al., 1990; Adams et al., 1995) and related economic development and stability (Rosenzweig and Parry, 1994), especially in the Mississippi Delta where agriculture is a cornerstone of the regional economy.

Of the climatological variables important to agriculture in the Mississippi Delta, precipitation is arguably the most important due to the high rates of evapotranspiration during the growing season, as well as the moisture required for local crops to succeed. However, precipitation is perhaps the most difficult climate variable to predict with respect to depth and coverage due to the myriad climatological and observational factors involved, especially during
the summer growing season when small-scale convective events provide a majority of the precipitation. Due to this, precipitation research is and has been of key importance to the maintenance and development of agriculture and water resource guidelines in the Mississippi Delta.

The best way to improve climatological and meteorological predictions of precipitation over an area is to first improve the observation capabilities. The Mississippi Delta has a distinct advantage in this respect in that there are currently three sources of precipitation measurements available: (1) radar-derived precipitation estimates from National Weather Service (NWS) NEXRAD Doppler radars, (2) surface observations from NWS recording stations, and (3) surface observations from US Department of Agriculture (USDA) Soil Climate Analysis Network (SCAN) recording stations. Each of these data sources provides independent hourly measurements/estimates of precipitation that are used in both operational and research applications. However, despite the advantageous of having several precipitation data sources, it is not known how the data sources compare with each other. This information is vital since radar-derived estimates have the potential to be used along with or in place of existing gauge-derived estimates to improve precipitation representation in related applications.

The primary objective of this project is to quantitatively describe the biases associated with three available precipitation measurement and estimation sources in the Mississippi Delta region: the NWS and SCAN surface gauge-based networks and radar-derived NEXRAD precipitation estimates. This will include analysis of individual patterns of precipitation recorded by each source, as well as comparative differences between each. Results will provide information regarding the general biases associated with the observations so that the data sources can be used interchangeably in operational and research initiatives.

Understanding the spatial and temporal patterns of precipitation over an area can provide invaluable information regarding local and regional surface and groundwater availability. Many water resource managers rely on estimates of total rainfall based on historical averages; however, this information is limited as it does not directly include frequency or duration of precipitation. As a result, the secondary objective of this project is to define the probability of precipitation over the Mississippi Delta. By incorporating information from the results of the primary objective, a high-resolution product based on the radar-derived precipitation product will be
developed to give better quantification of rainfall over the region. Results of this project will provide detailed information regarding precipitation patterns over the Mississippi Delta, allowing agriculture and water resource managers to make more accurate local-scale predictions and assessments of water supply and availability.

2. Data Collection

The study area for this project is defined as those counties in northwestern Mississippi and southeastern Arkansas where greater than 75% of the land area is less than 80 meters above sea level and the percent of land area used as cropland is at least 50% (Figure 1). This delineation allows for the inclusion of a large portion of the agricultural area in Mississippi and Arkansas, while excluding similar areas in Tennessee and Louisiana where surface meteorological station density decreases.

Within the defined study region, three hourly precipitation measurement and estimation sources are incorporated into the analysis. The first is National Weather Service (NWS) surface recording stations, including both ASOS automated surface observation system (ASOS) and non-ASOS recording stations. There are 13 stations within the study region with valid recorded data between 1996-2006, based on the National Climatic Data Center (NCDC) quality control routines (Figure 2a). The second data source includes Soil Climate Analysis Network (SCAN) sites, of which 13 surface recording stations were included in the study (USDA, 2006; Figure 2b). Again, only those stations with valid data between 1996-2006 were included. Although there is a relatively high spatial density of SCAN and NWS sites in the study area, it should be pointed out that not all stations have complete records between 1996-2006. This is especially true of the SCAN stations, where over half of the stations began recording precipitation over the last half of the study period. In an effort to include all available information in the analyses, especially with regards to recent observations, these stations were not removed from the analysis.

The third precipitation data source used in this project is multi-sensor precipitation estimates, derived from hourly WSR-88D data (Weather Surveillance Radar – 1988 Doppler; details of the methods and limitations of the products can be found in Fulton et al. [1998]). Radar-based precipitation estimates have become a useful and valuable tool in
hydrometeorological research because of their high spatial and temporal resolution. This is especially true in research related to small-scale or intense precipitation variability and distributed hydrologic modeling. However, since radar is a remotely sensed platform with inherent, though understood, limitations (i.e., beam blockage, false return signals, truncation error, etc.), certain care must be taken while working with related data fields. Although the NWS has developed algorithms designed to minimize the error in associated precipitation estimates, it is difficult to fully quantify and remove these errors; however, the study area for this project is unique in that it lies within the coverage of three independent radar installations (Figure 2c). This minimizes potential errors resulting from faults with a single radar, while the low elevation of the region further minimizes issues related to beam blockage.

Multi-sensor data are produced by combining hourly radar precipitation estimates (a.k.a., Stage I data), in the form of a digital precipitation array (DPA), with select hourly surface-based observations. The surface observations are used to calculate a corrective mean field gauge-radar bias using a Kalman filtering approach, which is a local adjustment to the radar-derived precipitation field (Smith and Krajewski, 1991). This is done for each individual radar coverage, resulting in corrected radar-based precipitation estimates, called Stage II data. The final process combines the individual corrected radar fields into a mosaic of coverages, resulting in a continuous field of multisensor precipitation estimates. These data, now labeled as a Stage III product, are manually quality controlled at NWS river forecast centers to remove areas of known contamination (Briedenbach et al., 1998; NOAA/NWS, 2007).

In recent years the Office of Hydrologic Development (OHD) of the NWS has made a transition from the Stage III processing algorithms to the updated Multisensor Precipitation Estimator (MPE) algorithm. The greatest advantage of the MPE is its ability to incorporate future satellite-based precipitation estimation products (Kondragunta and Seo, 2004). Despite the fact that the algorithm used to calculate the precipitation estimates has changed during the study period for this project, no correction has been made to adjust either the data or the study period. It is the variations in the precipitation time series resulting from these biases that are to be quantified through this study.

Stage III and MPE precipitation estimates are provided by the NWS in XMRG format, and are projected in the Hydrologic Rainfall Analysis Project (HRAP) coordinate system. The
HRAP coordinate system is a polar stereographic projection centered at 60°N / 105°W, with a nominal 4x4 km grid resolution. For the purposes of this study, the multisensor precipitation estimates were decoded such that the latitude and longitude of the respective HRAP grid cell center was associated with the corresponding precipitation value.

3. Methodology

3.1 Primary Objective

3.1.1 Point Analysis Techniques

Hourly precipitation analysis involved statistical descriptions of hourly precipitation data for the SCAN and multi-sensor estimates, along with calculation of correlation coefficients between associated time series. The NWS data were not included in the hourly analysis because only one of the included NWS observing gauges (Station 223627) measured in true hundredths of an inch while all other sites measured in tenths of an inch. This same station is used to calculate mean field biases in the multi-sensor precipitation product; therefore, the inherent statistical correlation with the radar field prohibits its use in direct hourly comparisons.

For hourly comparisons between the multi-sensor and SCAN networks, data for the nearest multi-sensor grid cell to each SCAN gauge was used. Only those gauges inside the study area were used, narrowing the number of SCAN stations used for analysis to nine (Figure 2). Descriptive statistics were calculated for both the multi-sensor and SCAN precipitation values assuming the data were gamma distributed, such that the associated shape (α) and scale (β) parameters were used to calculate the associated expected value (αβ) and variance (αβ²) of the individual distributions (Wilks, 2006). The shape and scale parameters were calculated using the maximum likelihood approximation method from Greenwood and Durand (1960).

Precipitation data are inherently highly skewed, making direct calculation of the correlation coefficient between data impractical. Additionally, Gunst (1995) showed that if temporal trends and autocorrelation exist within a time series, the associated correlations will overestimate the true spatial correlation. Despite this, the use of statistical correlation to quantify
the spatial structure of precipitation is well documented (Zawadzki, 1973). However, Stedingger (1981) showed that improved correlation values can be obtained if the skewed variables are logarithmically transformed, while Shimizu (1993) demonstrated that such a technique is indeed valid for analysis of precipitation data.

Habib et al. (2001) quantify the usefulness and robustness of using the bivariate mixed-lognormal distribution for comparison of precipitation time series. Consequently, the requisite calculation of the correlation coefficients between hourly multi-sensor and SCAN data was done using the method set forth by Shimizu (1993). This method involves transforming the associated precipitation time series to a log-normal distribution, separating the paired data into four distinct cases ([1] zero/zero, [2] zero/non-zero, [3] non-zero/zero, and [4] non-zero/non-zero), calculating the variances and means of the log-normal variables using expressions described in Shimizu (1993), and then incorporating the calculated values into the standard expression for the population correlation coefficient.

Daily comparisons between the multi-sensor and SCAN time series was done by summing up the associated hourly values from midnight to midnight local standard time (LST). Daily analysis was necessary because it is a common temporal resolution used in hydrologic and water resource applications, and because it reduces small-scale variations in the data that may influence statistical comparisons. Using the daily data, basic statistical indices were calculated for each paired time series including difference (multi-sensor – SCAN), ratio (multi-sensor / SCAN), and percent difference ([multi-sensor – SCAN] / multi-sensor). These indices, specifically the ratios and percent differences, have a high mathematical sensitivity to low or zero precipitation values; therefore, only non-zero paired precipitation values were included in the analysis. This can potentially remove a large portion of the dataset, but allows for a more precise description and comparison of rainfall when it does occur.

3.1.2 AREA-AVERAGED ANALYSIS TECHNIQUES

For spatial analysis purposes, it was necessary to calculate hourly mean areal precipitation values for the NWS and SCAN surface networks over the study area. This was done by first interpolating all available station data for a given hour from each network onto the
same HRAP grid used by the multi-sensor product. An inverse-distance weighting algorithm was used for the interpolation due to its inherent simplicity and widespread use. For the interpolation, the maximum and minimum number of points used to calculate precipitation at a given grid cell was five and three, respectively, with a maximum search radius of 100 km. After interpolating the hourly point data into hourly grids, the grid values were averaged to obtain hourly mean areal precipitation values.

Although other methods for interpolation could have been used, such as Kriging or Theissen polygons, the issue of data availability was an issue. During any given hour the number of available data points in either network could change depending on period of record, recording error, or station malfunction; therefore, a simple yet robust interpolation procedure was considered more desirable since each interpolation required a reassessment of the available data.

Once hourly mean areal precipitation values were calculated over the study region for all three data sources, daily total precipitation was calculated to make data analysis and representation more efficient and also to minimize inherent measurement noise in the respective datasets. This was done by summing hourly values of precipitation from midnight to midnight LST. After summing the data into daily sums, it was noticed that the NWS surface data contained a large number of missing values and a small number of zero values as compared to the other two datasets. It appeared that, in general, if no precipitation was reported at a NWS station, instead of recording a zero a missing record was included. This led to substantial inconsistencies between the descriptive statistical measures of the datasets; therefore, to maintain as much consistency as possible during the analysis, all records of zero daily total precipitation were removed from both the SCAN and multi-sensor products. In this way, only days with above-zero precipitation were included in the analysis.

3.2 Secondary Objective

Water resources in the Yazoo River watershed, which comprises a large part of the Mississippi Delta, are important because of the widespread agriculture in the basin. The region is characterized by extremely deep, rich soils deposited through repeated flooding of the Mississippi River. Although the region receives 130-140 cm of precipitation annually, high rates
of evapotranspiration during the summer lead to a need for agricultural irrigation. This is especially true for catfish and rice production, which require an average of 600mm day\(^{-1}\) and 900mm day\(^{-1}\) of water, respectively, to maintain production (YMD, 2006). Due to this, precipitation research is and has been of key importance to the maintenance and development of agriculture in the Mississippi Delta.

Radar-based precipitation estimates from the Stage III and MPE algorithms have become a valuable tool in hydrometeorological research due to their high spatial and temporal resolution (Young et al., 2000; Fuelberg et al., 2002). This is especially true in research related to local-scale precipitation variability, where surface gage networks lack the spatial density to measure detailed variations in rainfall. Although the Stage III and MPE precipitation estimates provide an excellent platform for studying precipitation distribution, there does exist some uncertainty in actual hourly precipitation values. This uncertainty arises due to both random and systematic errors in the multi-sensor product.

To lessen the effect of random error and measurement variability, as well as to make data analysis and representation more efficient, daily precipitation totals were used for this project instead of hourly estimates. These were calculated by summing all values for each day from 0000Z to 2300Z so that time zone and daylight savings time could be ignored. Additionally, as a final quality control check against non-random systematic errors, any daily precipitation totals that were more than three standard deviations above the overall mean for each individual basin were flagged. These values were then manually verified using external data sources, and if found to be caused by non-physical processes, substituted with a missing value identifier. Although this procedure cannot completely remove the effect of systematic errors resulting from sensor or algorithmic issues, it can minimize their impact on the data set and associated analysis.
4. Project Results

4.1 Primary Objective

4.1.1 Hourly Point-scale Analysis

Precipitation patterns over the lower Mississippi River alluvial valley have a distinct seasonal pattern, with the greatest depth of precipitation occurring in the late fall and early winter and the lowest occurring in the summer. This seasonality is primarily a result of the latitude of the study area, such that cool season weather patterns are based on a more baroclinic environment, leading to a higher frequency of frontal convection and stratiform precipitation, while the warm season is dominated by a more barotropic environment with scattered cumuliform precipitation. Based on this pattern, the point-scale analysis of hourly precipitation values from the multi-sensor and SCAN observation platforms is done separately for the warm season (April - September) and cool season (October - March). This approach will provide more information as to how the SCAN and multi-sensor data sources compare under different precipitation patterns. During the warm season, the multi-sensor precipitation estimates are greater than the associated SCAN observations at all locations ($\mu = 0.07$; Table 1). Although there are too few points to determine spatial influences, it should be noted that the greatest differences are found at sites 2086, 2032, and 2087 (0.17, 0.09, and 0.08 mm, respectively), all of which are located under the coverage of only the Jackson, Mississippi radar. This fact could indicate that precipitation estimates from the Jackson, Mississippi radar are biased towards higher values; however, further work is needed to verify that this is true. Variances between the data sources are roughly equal, although multi-sensor estimates are more dispersed at all locations relative to the associated SCAN values.

Correlation coefficients between the multi-sensor and SCAN data during the warm season are similar at all locations, ranging from $\rho = 0.48 - 0.59$ ($\mu = 0.55$; Table 1). This shows that the data sources are only moderately correlated, the physical reasons for which are difficult to accurately determine. To truly verify a precipitation measurement a ground-truth value must be used for comparison, which is often assumed to be a surface-based observation. The fact that
surface gauges often underestimate rainfall (due to issues such as wind undercatch, splashing, and evaporation) while radar-estimates tend to overestimate precipitation (due to assumptions in the Z-R relationship, false return signals, issues with frozen precipitation, etc.) leads one to conclude that the poor correlation between the SCAN and multi-sensor data is a combination of independent and additive errors.

During the cool season the differences between the SCAN and multi-sensor data sources are reduced, with average differences between the means and variances both equaling 0.01 mm (Table 1). Additionally, the correlation coefficients between the data sources increases substantially at all locations, ranging from \( \rho = 0.59 \rightarrow 0.72 \). The increase in correlation and decrease in mean difference and dispersion is likely a result of a change to stratiform precipitation patterns over the study area. Under these conditions, precipitation rate is lower while droplet size becomes more uniform, which effectively decreases the errors associated with radar precipitation estimates. The issue of undercatch with the SCAN gauges may also decrease, although these changes are likely minimal. The end result is a closer approximation of precipitation rate and depth by the radar-based multi-sensor estimate, although unquantifiable errors from both data sources prohibit a higher correlation.

### 4.1.2 Daily Point-scale Analysis

Analysis of mean daily precipitation, calculated by summing the hourly rainfall values for each day, allows for a more general quantification of the biases between the surface and radar-based rainfall data sources by removing short-term variability from each dataset. Results show that the multi-sensor data are, on average, 0.31 mm day\(^{-1}\) higher than the SCAN values, indicating an overestimation by the multi-sensor product (Table 2). Again, the term overestimation may be a misnomer since a ground-truth precipitation value is unavailable. These results agree with the hourly analysis; however, the percent difference values are contrary to these results, showing the SCAN data as having an average bias of 38% above the multi-sensor estimates. The reasons for this incongruity stem from the sensitivity of the bias calculations at low precipitation values, such that a small difference relative to a small multi-sensor precipitation estimate can lead to large percent differences. What can be illustrated from these results is that at low daily
precipitation depths, the surface-based SCAN gauges observe a greater precipitation depth than the multi-sensor product.

Looking at the warm and cold seasons separately shows that the differences between the data sources generally increases during the summer months and decreases during the winter months. During the warm season, the average difference increases to 0.59 mm day\(^{-1}\); however, the magnitude of nearly all differences increases, despite the direction of the bias (Table 2). During the cool season the average difference decreases to -0.11 mm day\(^{-1}\), which upon initial interpretation indicates that the multi-sensor data show a negative bias with respect to the SCAN data. The average percent difference during the cool season is substantially lower than during the warm season (-0.49 and -0.37 mm day\(^{-1}\), respectively), which gives further credence to the possibility of precipitation overestimation by the SCAN gauges during stratiform-type precipitation events.

To minimize the effects of small precipitation values on the calculation of percent difference, the point-analysis is limited to instances in which the daily total precipitation given by the multi-sensor estimates is at least 25 mm day\(^{-1}\). This will allow for an improved quantification of the measurement bias between the SCAN and multi-sensor precipitation data sources. The 25 mm day\(^{-1}\) criteria was chosen because it roughly corresponds to a natural break in the respective precipitation time series, an example of which is given in Figure 3, and also because it is a common value denoting a day with heavy precipitation.

Relative to all precipitation values meeting the above criteria, the difference between the SCAN and multi-sensor data sources increases to an average of 2.91 mm day\(^{-1}\) (Table 2) while the percent difference decreases substantially to 5%. The differences in daily precipitation depth during the warm and cold season are above and below this value (4.10 mm day\(^{-1}\) and 2.58 mm day\(^{-1}\), respectively), which agrees with previous patterns. Unlike the analysis utilizing precipitation depths less than 25 mm day\(^{-1}\), the multi-sensor estimates are shown to overestimate precipitation relative to the SCAN data. The percent difference values match this result, showing that multi-sensor estimates are, on average, 6% greater than SCAN observations during the cool season. This value is only slightly higher (7%) during the warm season, which indicates that at high daily precipitation depths, which commonly occur during the summer when cumuliform
precipitation events are more common, the bias between the multi-sensor and surface-based SCAN networks is relatively small and stable.

4.1.3 Daily Mean Areal Precipitation Analysis

Due to the seasonality of the biases between the data sources described previously (maximum in warm season, minimum in cool season), a time series analysis of the biases over the entire study period was considered necessary. However, the large number of missing data points in the time series, along with the relatively random distribution of the missing values within the study period, did not allow for an accurate and reliable method of time series analysis. As a result, the data were subject to a more informal analysis based on running means and variances over the 1996-2006 study period. This was done by first calculating the differences between each data source, then standardizing the values by subtracting the overall means and dividing by the standard deviation. The results yielded three standardized time series with a mean of zero and a standard deviation of one for the NWS – SCAN, NWS – multi-sensor, and SCAN – multi-sensor data. To minimize inherent noise in the data while providing a good description of the relative patterns and variability of precipitation biases over the study period, a 100-day running mean and standard deviation were calculated for each set of paired data. Results from this analysis cannot be used to interpret absolute biases between the data sources since they have been normalized relative to the means, but are a good indication of how the biases change over the study period.

The bias time series of the NWS and SCAN data sources remains relatively constant throughout the study period, despite several high magnitude peaks in 2003. The 100-day running mean indicates that there was a maximum negative bias during the winter of 2001-2002 (-0.83 standard units), and a secondary minimum in the fall of 2002 (-0.49 standard units). Conversely, a maximum positive local bias occurred during the summer of 2002 (0.41 standard units), illustrating the seasonal variation in precipitation biases between these two data sets. The variability of this bias remained fairly high until the late summer of 2003 when it began to decrease markedly, most likely a result of an increase in the number of stations within the SCAN network.
The bias between the NWS and multi-sensor precipitation estimates shows a general decrease from 1996 to early 2003 before stabilizing throughout the remainder of the study period. This transition is a possible indication of a modification to the multi-sensor precipitation estimation process; however, the variability of the bias between the data shows no distinct change with the stabilization of the precipitation bias. Also, while there is a slight oscillatory pattern in the data after 2000, reflecting the seasonality of the bias (lower in the winter, higher in the summer), there is no apparent oscillation before this time. In fact, from late 1997 to late 2000, there was little change at all in the bias values other than a general decrease.

Regarding the SCAN and multi-sensor precipitation data, the same general pattern of decreasing bias from the beginning of the study period to early 2003 is apparent. This clearly shows that it is the multi-sensor precipitation estimates that have changed during this time and not the surface-based observation networks. Subsequent to early 2003, the biases between the SCAN and multi-sensor data sources becomes more consistent and is mirrored by a slight decrease in variability. This decrease in variability is likely a result of an increase in the number of SCAN observation sites, since there is also a slight decrease in variability in the NWS and SCAN precipitation biases. These results generally show that as a result of an increase in the density of the SCAN network and a modification to the multi-sensor precipitation processing system, the bias between the two datasets has become more stable and less variable over the study period.

4.2 Secondary Objective

4.2.1 Mean Annual and Monthly Precipitation Analysis

Precipitation in the Yazoo River watershed peaked in the early 2000s, centered on a maximum of 13.0mm day\(^{-1}\) in 2002. Interestingly, secondary peaks in 1997, 2004, and 2006 are accompanied by peaks in the mean hourly areal precipitation. Although correlations between these data are moderate (\(R^2 = 0.56\)), this does show that changes in the distribution of precipitation in the Yazoo River watershed may be as if not more important to overall water availability than variations in precipitation intensity. This is an important result, since high
intensity precipitation over agricultural areas is often considered a negative due to heightened erosion processes and soil compaction. Regarding changes in frequency of precipitation over the Yazoo River watershed, the average number of hours with recorded precipitation per day varies only slightly, remaining between roughly 7 – 9 hours day\(^{-1}\). The relationship between precipitation frequency and amount is weak \((R^2 = 0.39)\), but does work to augment the statement that precipitation variability in this region is based more on precipitation frequency and extent and not precipitation intensity.

Monthly mean precipitation in the Yazoo River watershed shows no distinct seasonal pattern in mean daily precipitation, although there is a slight minimum during the late summer and early fall \((6.6 - 6.7 \text{ mm day}^{-1})\). However, there are clearly defined summer maximums and minimums in precipitation frequency \((11.45 \text{ hours day}^{-1})\) and extent \((2645 \text{ km}^2)\), respectively, both centered on July. This pattern suggests that a high frequency of precipitation during the summer is countered by a low areal extent, similar to the cumuliform precipitation patterns seen in both the Savannah River watershed and the southern Florida region. However, during the winter the areal extent of precipitation in the Yazoo River basin overcomes the decrease in precipitation frequency, leading to a slight increase in overall monthly rainfall.

4.2.2 Seasonal Precipitation Analysis

To better understand the patterns of precipitation over the study area, a detailed spatial analysis was done for the summer and winter months, defined as April through September and October through March, respectively. This separation marks an even division of the water year for the southeast US, and clearly marks the change in precipitation patterns given by the monthly mean values of precipitation amount, frequency, and areal extent.

Summer precipitation patterns in the Yazoo River watershed are fairly variable, with mean daily precipitation depths ranging from over 4.0 mm day\(^{-1}\) in the northeast to less than 2.0 mm day\(^{-1}\) in the south (Figure 4a). Precipitation frequency shows the same general pattern, although the range of values shows a lower relative difference (Figure 4b). These results show that higher intensity and more frequency rainfall occurs in the central and eastern edge of the basin, possibly due to the local influence of moisture from the Gulf of Mexico along with the
influence of mesoscale and synoptic-scale boundaries. However, the high density of agriculture and the associated irrigation along the western edge of the basin, known as the lower Mississippi River alluvial valley, or locally as the Mississippi Delta, may have an influence on the given rainfall distribution.

Research has shown that agriculture in the western areas of the Yazoo River watershed can have an influence on regional weather variability through land use and vegetation patterns (Brown and Arnold, 1998). Specifically, soil type and vegetation can affect the energy and moisture fluxes into the atmospheric boundary layer through spatial variations in evapotranspiration, albedo, and surface heat transport (Hong et al., 1995; Segal et al., 1988; Ookouchi et al., 1984; Rabin et al., 1990; Mahfouf et al., 1987; Boyles et al., 2007). Work by Brown and Wax (2007) show that a temperature gradient exists between the eastern and western portions of the Yazoo River watershed, the former of which is the low-elevation floodplain of the Mississippi River. During the summer months, maximum daily temperatures within this section of the watershed are 0.5°C warmer than areas outside the Mississippi River floodplain, which could possibly effect precipitation patterns. Brown and Wax (2007) suggest that variations in soil type and/or soil moisture could be the cause of the temperature difference, primarily through variations in the surface heat fluxes. Based on analysis of the sandhill effect in the Savannah River basin, a similar phenomenon could be occurring within the Yazoo River watershed; therefore, further research into this topic is currently underway in an effort to better quantify precipitation patterns for water resource management and agriculture. Again, the multi-sensor precipitation product is ideally suited for this study, since the enhanced detail of the precipitation estimates can better indicate local-scale variations in rainfall.

The Yazoo River watershed is the only basin in this study that receives more precipitation during the winter (3.6 mm day\(^{-1}\)), due in part to the greater areal extent of precipitation over 3 mm day\(^{-1}\) (Figure 4c). This can be seen by a decrease in the range of mean daily precipitation values from 2.7 mm day\(^{-1}\) to 1.9 mm day\(^{-1}\), relative to the warm season, due primarily to an increase in minimum precipitation. Precipitation over the region is consistently and uniformly high in both depth and frequency, with local maxima in the central parts of the basin (Figure 4c-d). This pattern is critically important to agriculture, the dominant economic resource of the region, in that extensive but moderate intensity rainfall is able to satisfy soil moisture
requirements and groundwater recharge while minimizing soil compaction and erosion. This allows for a higher percentage of the precipitation to be stored in the groundwater system before running off into surface hydrologic features.

5. Future Research

Research has shown that agriculture can have an influence on regional weather variability through land use and vegetation patterns (Brown and Arnold, 1998). Specifically, soil type and vegetation play a key role in determining the dynamics of energy and moisture transport into the atmospheric boundary layer through spatial variations in evapotranspiration, albedo, and surface heat fluxes (Hong et al., 1995; Segal et al., 1988; Ookouchi et al., 1984; Rabin et al., 1990; Mahfouf et al., 1987; Boyles et al., 2007). These effects are clearly well documented, and can occur in various climate zones given weak synoptic forcing. Additionally, agricultural land use can influence the dynamics of the boundary layer through variations in surface roughness over the growing season, effectively modifying existing sub-synoptic and mesoscale flow regimes by varying the intensity of turbulent mixing through the radix layer.

The energy, moisture, and turbulent fluxes all have strong influences on the generation and strength of mesoscale circulations, and therefore precipitation. As a result, variations in land use and/or soil type can lead to changes in regional precipitation patterns (Anthes, 1984). Several studies have demonstrated the role of the sand-clay soil boundary in eastern North Carolina (a.k.a., the “Sandhill Effect”) on mesoscale surface convergence and convective precipitation (Boyles et al., 2007; Koch and Ray, 1997). Similar soil contrasts exist within the lower Mississippi River alluvial valley, and results from Dyer (2008) indicate that precipitation patterns in and around the Mississippi Delta may be influenced by changes in land use, soil type, and/or soil moisture. Abnormal temperature variations exist in the region as a result of spatial variations in soil and vegetation (Raymond et al., 1994; Brown and Wax, 2007), which could be an indicator of possible boundary layer modification through surface influences, resulting in the generation of mesoscale circulations and precipitation.

The first future research topic involves the analysis of high-resolution precipitation data over the lower Mississippi River alluvial valley to determine if precipitation patterns are
influenced by surface soil and/or vegetation variations. Initial findings indicate that a distinct dipole pattern exists with a rainfall minimum over the Mississippi Delta and a maximum approximately 150 km to the east (Figure 5). Further analysis of this pattern over a monthly and seasonal basis may provide information regarding the temporal and spatial extent of regional rainfall.

To better understand the causes of the observed rainfall distribution, it is necessary to perform a sensitivity analysis of convective forcing mechanisms and the associated precipitation generation. This type of study is best performed through numerical modeling; therefore, a second future project involves the use of the Weather Research and Forecasting (WRF) model to identify the surface and atmospheric mechanisms most responsible for the existing rainfall distribution. Although modeling studies have been carried out in other locations to examine the sensitivity of mesoscale circulations to surface characteristics (Mahfouf et al., 1987; Boyles et al., 2007; Hong et al., 1995), it is necessary to first study observed data to determine if a relationship is visible. Subsequent studies using mesoscale numerical models may then be appropriate to quantify the sensitivity of surface convergence zones to soil and vegetation. This strengthens the validity of performing an observational analysis of rainfall, followed by an associated analysis of simulated rainfall distribution over the same region. Results of this project will provide detailed information regarding precipitation patterns over the Mississippi Delta, allowing agriculture and water resource managers to make more accurate local-scale predictions and assessments of water supply and availability.
Figure 1. Topography and agriculture of Mississippi Delta region in northwest Mississippi and southeast Arkansas. Cutout shows location of study region in southern United States. [From Dyer (2008)]

Figure 2. Distribution of (a) NWS surface recording gauges, (b) SCAN surface recording gauges, and (c) NEXRAD radar installations used to calculate radar-estimated precipitation values over the study region (circles indicate a 230 km radar coverage area for each installation). [From Dyer (2008)]
Figure 3. Difference, ratio, and percent difference values for precipitation over SCAN gauge 2046. Solid horizontal black lines denote a 20-point running mean for the respective time series, while the solid vertical lines indicate the 25 mm threshold. [From Dyer (2008)]
Fig. 4. Yazoo River watershed precipitation patterns for warm season (April – September) mean daily precipitation (a) depth and (b) frequency and cool season (October – March) mean daily precipitation (c) depth and (d) frequency. [From Dyer (2009a)]
Figure 5. Mean daily precipitation (mm) over the Mississippi Delta and surrounding regions for all synoptically weak days from 1996-2007.
Table 1. Hourly mean, variance, and correlations for warm and cold-season precipitation at select SCAN stations and adjacent NEXRAD multi-sensor grid points. Mean and variance were calculated assuming a gamma distribution while correlations were calculated assuming a bivariate mixed-lognormal distribution. [From Dyer (2008)]

<table>
<thead>
<tr>
<th>SCAN ID</th>
<th>Data source</th>
<th>Warm Season</th>
<th>Cool Season</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean</td>
<td>Variance</td>
</tr>
<tr>
<td>2091</td>
<td>SCAN Multi-sensor</td>
<td>0.11</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td>Multi-sensor</td>
<td>0.19</td>
<td>0.05</td>
</tr>
<tr>
<td>2046</td>
<td>SCAN Multi-sensor</td>
<td>0.14</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td>Multi-sensor</td>
<td>0.16</td>
<td>0.03</td>
</tr>
<tr>
<td>2084</td>
<td>SCAN Multi-sensor</td>
<td>0.14</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td>Multi-sensor</td>
<td>0.22</td>
<td>0.07</td>
</tr>
<tr>
<td>2034</td>
<td>SCAN Multi-sensor</td>
<td>0.16</td>
<td>0.04</td>
</tr>
<tr>
<td></td>
<td>Multi-sensor</td>
<td>0.22</td>
<td>0.06</td>
</tr>
<tr>
<td>2035</td>
<td>SCAN Multi-sensor</td>
<td>0.15</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td>Multi-sensor</td>
<td>0.19</td>
<td>0.05</td>
</tr>
<tr>
<td>2070</td>
<td>SCAN Multi-sensor</td>
<td>0.16</td>
<td>0.04</td>
</tr>
<tr>
<td></td>
<td>Multi-sensor</td>
<td>0.21</td>
<td>0.06</td>
</tr>
<tr>
<td>2032</td>
<td>SCAN Multi-sensor</td>
<td>0.12</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td>Multi-sensor</td>
<td>0.21</td>
<td>0.05</td>
</tr>
<tr>
<td>2086</td>
<td>SCAN Multi-sensor</td>
<td>0.01</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>Multi-sensor</td>
<td>0.18</td>
<td>0.05</td>
</tr>
<tr>
<td>2087</td>
<td>SCAN Multi-sensor</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>Multi-sensor</td>
<td>0.09</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Table 2. Difference (multi-sensor – SCAN), ratio (multi-sensor / SCAN), and percent difference ([multi-sensor – SCAN] / multi-sensor) values for mean daily precipitation estimates from multi-sensor and SCAN data. [From Dyer (2008)]

<table>
<thead>
<tr>
<th>SCAN ID</th>
<th>All Values</th>
<th>Warm Season</th>
<th>Cool Season</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Difference</td>
<td>% Diff</td>
<td>Difference</td>
</tr>
<tr>
<td>2091</td>
<td>-0.03</td>
<td>-0.49</td>
<td>-1.09</td>
</tr>
<tr>
<td>2046</td>
<td>0.60</td>
<td>-0.34</td>
<td>1.46</td>
</tr>
<tr>
<td>2084</td>
<td>-0.34</td>
<td>-0.05</td>
<td>-1.00</td>
</tr>
<tr>
<td>2034</td>
<td>1.39</td>
<td>-0.33</td>
<td>1.52</td>
</tr>
<tr>
<td>2035</td>
<td>1.23</td>
<td>-0.23</td>
<td>3.04</td>
</tr>
<tr>
<td>2070</td>
<td>0.11</td>
<td>-0.21</td>
<td>1.33</td>
</tr>
<tr>
<td>2032</td>
<td>-0.47</td>
<td>-1.06</td>
<td>0.32</td>
</tr>
<tr>
<td>2086</td>
<td>0.39</td>
<td>-0.35</td>
<td>0.67</td>
</tr>
<tr>
<td>2087</td>
<td>-0.09</td>
<td>-0.35</td>
<td>-0.95</td>
</tr>
</tbody>
</table>

Precipitation values where associated multi-sensor estimate is > 25 mm

<table>
<thead>
<tr>
<th>SCAN ID</th>
<th>All Values</th>
<th>Warm Season</th>
<th>Cool Season</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Difference</td>
<td>% Diff</td>
<td>Difference</td>
</tr>
<tr>
<td>2091</td>
<td>2.34</td>
<td>0.04</td>
<td>-2.37</td>
</tr>
<tr>
<td>2046</td>
<td>3.38</td>
<td>0.11</td>
<td>4.89</td>
</tr>
<tr>
<td>2084</td>
<td>-1.04</td>
<td>-0.07</td>
<td>-5.82</td>
</tr>
<tr>
<td>2034</td>
<td>9.25</td>
<td>0.18</td>
<td>7.94</td>
</tr>
<tr>
<td>2035</td>
<td>-0.11</td>
<td>-0.04</td>
<td>8.86</td>
</tr>
<tr>
<td>2070</td>
<td>2.61</td>
<td>0.08</td>
<td>4.94</td>
</tr>
<tr>
<td>2032</td>
<td>2.19</td>
<td>0.03</td>
<td>3.91</td>
</tr>
<tr>
<td>2086</td>
<td>3.82</td>
<td>0.10</td>
<td>7.57</td>
</tr>
<tr>
<td>2087</td>
<td>3.77</td>
<td>0.05</td>
<td>7.01</td>
</tr>
</tbody>
</table>
References


Dyer, J.L., 2009b: Comparison of multi-sensor precipitation estimates over the lower Mississippi River alluvial plain. 23rd Conference on Hydrology, American Meteorological Society, Phoenix, AZ.


6. Information Transfer and Dissemination

The results of the research conducted during the course of this project have been disseminated through peer-reviewed publications and conference presentations. The results from the primary objective are included in a manuscript that is currently under review in *Water Resources Research* (Dyer, 2009a). Additionally, early findings were presented at the 103rd annual meeting of the Association of American Geographers (Dyer, 2007a), while final results were presented at the 23rd Conference on Hydrology at the annual meeting of the American Meteorological Society (Dyer, 2009b).

The results from the secondary objective are included in a manuscript that has been published in *Physical Geography* (Dyer, 2008). Preliminary results were also presented at the 10th annual meeting of the International Geographical Union (Dyer, 2007b).

Final results of the project, including conclusions from both project objectives, will be presented at the Mississippi Water Resources Conference in August.

7. Student Training

A research assistant, Heather Hyre, was funded during Fall semester 2008 through this project, housed in the Department of Geosciences. Ms. Hyre is a first year master’s student studying operational/applied meteorology, and although she is not pursuing a thesis in direct association with this project, she is utilizing the associated data and methods to investigate precipitation distribution and related surface influences at locations in the northeast US.
8. Financial Summary

Initial budget for funded project:

<table>
<thead>
<tr>
<th>Cost Category</th>
<th>Percent Time Devoted to Project</th>
<th>Total Salary</th>
<th>Federal Contribution</th>
<th>State Contribution</th>
<th>Matching Contribution</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Salaries and Wages</td>
<td>PI 15%</td>
<td>$51,665</td>
<td>$3,875</td>
<td>$3,575</td>
<td>$0</td>
<td>$7,450</td>
</tr>
<tr>
<td></td>
<td>GRA 50%</td>
<td>$12,000</td>
<td>$3,000</td>
<td>$3,000</td>
<td>$0</td>
<td>$6,000</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td></td>
<td>$6,875</td>
<td>$6,575</td>
<td>$0</td>
<td>$13,450</td>
</tr>
<tr>
<td>2. Fringe Benefits</td>
<td></td>
<td></td>
<td>$1,301</td>
<td>$1,202</td>
<td>$0</td>
<td>$2,503</td>
</tr>
<tr>
<td>3. Supplies</td>
<td></td>
<td></td>
<td>$140</td>
<td>$140</td>
<td>$0</td>
<td>$280</td>
</tr>
<tr>
<td>4. Permanent Equipment</td>
<td></td>
<td></td>
<td>$600</td>
<td>$600</td>
<td>$0</td>
<td>$1,200</td>
</tr>
<tr>
<td>5. Travel</td>
<td></td>
<td></td>
<td>$1,510</td>
<td>$987</td>
<td>$0</td>
<td>$2,497</td>
</tr>
<tr>
<td>6. Other Direct Costs</td>
<td></td>
<td></td>
<td>$2,232</td>
<td>$2,232</td>
<td>$20,000</td>
<td>$24,465</td>
</tr>
<tr>
<td>Total Direct Costs</td>
<td></td>
<td></td>
<td>$12,658</td>
<td>$11,737</td>
<td>$20,000</td>
<td>$44,394</td>
</tr>
<tr>
<td>8. Indirect Costs</td>
<td></td>
<td></td>
<td>$0</td>
<td>$0</td>
<td>$8,914</td>
<td>$8,914</td>
</tr>
<tr>
<td>9. Total Estimated Costs</td>
<td></td>
<td></td>
<td>$12,658</td>
<td>$11,737</td>
<td>$28,914</td>
<td>$53,308</td>
</tr>
</tbody>
</table>

Expenditures during quarterly reporting periods:

1st quarter [3/1/2008 – 6/30/2008]:
   Federal: $0.00, Non-Federal: $0.00, Cost Share: $0.00

2nd quarter [7/1/2008 – 9/30/2008]:
   Federal: $1,306.80, Non-Federal: $2,180.07, Cost Share: $0.00

3rd quarter [10/1/2008 – 12/31/2008]:
   Federal: $1265.25, Non-Federal: $1265.25, Cost Share: $0.00

   Federal: $9,510.73, Non-Federal: $8,305.56, Cost Share: $20,000.00
Monitoring and Modeling Water Pollution in Mississippi Lakes

Basic Information

<table>
<thead>
<tr>
<th>Title:</th>
<th>Monitoring and Modeling Water Pollution in Mississippi Lakes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Number:</td>
<td>2008MS81B</td>
</tr>
<tr>
<td>Start Date:</td>
<td>7/1/2008</td>
</tr>
<tr>
<td>End Date:</td>
<td>6/30/2009</td>
</tr>
<tr>
<td>Funding Source:</td>
<td>104B</td>
</tr>
<tr>
<td>Congressional District:</td>
<td>1</td>
</tr>
<tr>
<td>Research Category:</td>
<td>Water Quality</td>
</tr>
<tr>
<td>Focus Category:</td>
<td>Water Quality, Surface Water, Recreation</td>
</tr>
<tr>
<td>Descriptors:</td>
<td>None</td>
</tr>
<tr>
<td>Principal Investigators:</td>
<td>Cristiane Q. Surbeck</td>
</tr>
</tbody>
</table>

Publication
Mississippi Water Resources Research Institute (MWRRI)

Quarterly Report – (Combined) (From) 07/01/08 – (To) 03/31/09

Reports due: 1st (March 31); 2nd (June 30); 3rd (Sept. 30); 4th (Dec. 31)

Note: Please complete form in 11 point font and do not exceed two pages. You may reference and append additional material to the report.

SECTION I: Contact Information

Project Title: Monitoring and Modeling Water Pollution in Mississippi Lakes
Principal Investigator: Cristiane Q. Suerbeck
Institution: University of Mississippi
Address: Department of Civil Engineering, 203 Carrier Hall, University, MS 38677-1848
Phone/Fax: 662-915-5473, 662-915-5523
E-Mail: csuerbeck@olemiss.edu

SECTION II: Programmatic Information

Approximate expenditures during reporting period:

Federal: $628.66, Non-Federal: $0, Cost Share: $0

Equipment (and cost) purchased during reporting period:
Deionized water vials: $114.48
Rubber plugs: $4.92
Service: analysis of samples for total organic carbon (TOC) at ETC Laboratories, Memphis, TN:
$485 + $24.26 (shipping)

Progress Report (Where are you at in your work plan):
1. Conducted a microcosm study on Toby Tubby Creek water. Currently validating data and planning data analysis scheme. Work conducted by students in the Special Projects course titled “Projects in Surface Water Quality Modeling” under the supervision of the PI.
2. Generated a draft report titled “Estimating Kinetic Rate Constants for Die-Off of E. coli in an Urban and Rural Sub-watershed.”
3. Conducted a third microcosm study on combined water and sediment from Thompson Creek.
4. Continued working on conceptual models for microcosm studies and calculating decay rate constants.
5. Evaluating different mathematical models to simulate the bacteria decay curve.

Problems Encountered: Fitting the decay rate constants from this research to the modeling software CCHE-GUI, Beta version 3.0, as described in the proposal, will not yield accurate results because there is no accurate flow measurement at the field sites. Instead, the decay rate constants will be provided to the National Center for Computational Hydroscience and Engineering (NCCHE) to use their CCHE software on other sites, but with the decay rate constants found in this research.
Publications/Presentations (Please provide a citation and if possible a .PDF of the publication or PowerPoint): A draft report titled "Estimating Kinetic Rate Constants for Die-Off of E.coli in an Urban and Rural Sub-watershed" is in progress and will be revised during the next quarter. One Master's thesis is anticipated from this work by August 2009.

Student Training (list all students working on or funded by this project)

<table>
<thead>
<tr>
<th>Name</th>
<th>Level</th>
<th>Major</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alison Kinnaman</td>
<td>Master's</td>
<td>Environmental Engineering</td>
</tr>
<tr>
<td>John Mark Henderson</td>
<td>Senior</td>
<td>Civil Engineering</td>
</tr>
<tr>
<td>Keah Y. Lim</td>
<td>Senior</td>
<td>Civil Engineering</td>
</tr>
<tr>
<td>Casey Wilson</td>
<td>Senior</td>
<td>Chemical Engineering</td>
</tr>
<tr>
<td>Shannon Wilson</td>
<td>Master's</td>
<td>Environmental Engineering</td>
</tr>
</tbody>
</table>

Next Quarter Plans:
1. Conduct additional microcosm studies at lower Sardis Lake and data validation.
2. Continue framing conceptual models.
3. Calculate kinetic rate constants for E. coli based on the results of the new microcosm studies.
4. Revise draft report.
5. Start preparing Master's thesis. (1-5 were 7/1/08 - 12/31/08)
6. Conduct additional microcosm studies at lower Sardis Lake and data validation.
7. Calculate kinetic rate constants for E. coli based on the results of the new microcosm studies.
8. Run statistics on E. coli and nutrients to establish relationships between nutrients and E. coli decay.
9. Continue preparing Master's thesis.(6-9 were 1/1/09 - 3/31/09)

<table>
<thead>
<tr>
<th>Section III. Signatures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Manager</td>
</tr>
</tbody>
</table>
Watershed Assessment and Education

Basic Information

<table>
<thead>
<tr>
<th>Title:</th>
<th>Watershed Assessment and Education</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Number:</td>
<td>2008MS82B</td>
</tr>
<tr>
<td>Start Date:</td>
<td>7/1/2008</td>
</tr>
<tr>
<td>End Date:</td>
<td>6/30/2009</td>
</tr>
<tr>
<td>Funding Source:</td>
<td>104B</td>
</tr>
<tr>
<td>Congressional District:</td>
<td>02</td>
</tr>
<tr>
<td>Research Category:</td>
<td>Water Quality</td>
</tr>
<tr>
<td>Focus Category:</td>
<td>Water Quality, Education, Surface Water</td>
</tr>
<tr>
<td>Descriptors:</td>
<td>None</td>
</tr>
<tr>
<td>Principal Investigators:</td>
<td>Maifan Silitonga</td>
</tr>
</tbody>
</table>

Publication
SECTION I: Contact Information

Project Title: Watershed Assessment and Education  
Principal Investigator: Maifan Silitonga, Ph.D.  
Institution: Alcorn State University  
Address: 1000 ASU Drive, Alcorn State, MS 39096  
Phone/Fax: 601-877-6534; 601-877-6523  
E-Mail: msilitonga@alcorn.edu

SECTION II: Programmatic Information

Approximate expenditures during reporting period:

Federal: $3,892.90  Non-Federal: $4,592.47  Cost Share: $8,485.05

Cost share was incurred from faculty, staff, and student in the effort to prepare this project starting from establishing internal account, preparing or identifying instrumentations/equipment, and identifying water bodies to collect water samples from. $3,162.90 for student wages and $4,592.47 for faculty and staff hours including fringe benefits.

Equipment (and cost) purchased during reporting period:
Standards and calibration solutions for water testing instrument. Repaired sensors and ordered new probes (Electric Conductivity and Nitrate probes)

Progress Report (Where are you at in your work plan):
- Water testing instrument (the only one) needed calibration and probes replacement.
- Purchased standards and calibration solutions.
- Repaired or DO probes

Problems Encountered:
Instrument (Water quality monitor sonde) needed calibration. Technical person from the company was available to come to campus on January 26, 2009. Probes needed to be replaced. Probes and some calibration solutions have been delivered (March 06, 2009) while other chemical solutions needed (for testing total Phosphate) are still in the process. Student decided not to continue in the program (Falcia McDonald).

Publications/Presentations (Please provide a citation and if possible a .PDF of the publication or PowerPoint): N/A

Student Training (list all students working on or funded by this project)

<table>
<thead>
<tr>
<th>Name</th>
<th>Level</th>
<th>Major</th>
</tr>
</thead>
<tbody>
<tr>
<td>Falcia McDonald</td>
<td>MS</td>
<td>Plant &amp; Soil Science, Environmental Science</td>
</tr>
<tr>
<td>Rosner Buie</td>
<td>MS</td>
<td>Plant &amp; Soil Science, Environmental Science</td>
</tr>
<tr>
<td>Dan Moore</td>
<td>MS</td>
<td>Plant &amp; Soil Science, Environmental Science</td>
</tr>
</tbody>
</table>
Next Quarter Plans:
1. Collect water and soil samples
2. Test water samples and send soil samples for testing

Maifan Silitonga, Ph.D.
Information Transfer Program Introduction

The Mississippi Water Resources Research Institute addresses research and outreach efforts targeted at maintaining plentiful, quality water supplies throughout the state. The Institute is a hub for information and expertise on water resources issues within the state and region. We do this in full partnership with our public and private cooperators.

The Mississippi Water Resources Research Institute is committed to providing public outreach, education opportunities, and assisting with economic development activities. Researchers and students have the opportunity to present their research by giving oral and poster presentations. Also included are plenary sessions and workshops. Those persons subscribed to the MWRRI listserv receive newsletters, award opportunity notices, and timely water-related information.
## Information Transfer Program-Publications

### Basic Information

<table>
<thead>
<tr>
<th><strong>Title:</strong></th>
<th>Information Transfer Program-Publications</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Project Number:</strong></td>
<td>2006MS69B</td>
</tr>
<tr>
<td><strong>Start Date:</strong></td>
<td>3/1/2006</td>
</tr>
<tr>
<td><strong>End Date:</strong></td>
<td>2/28/2009</td>
</tr>
<tr>
<td><strong>Funding Source:</strong></td>
<td>104B</td>
</tr>
<tr>
<td><strong>Congressional District:</strong></td>
<td>3rd</td>
</tr>
<tr>
<td><strong>Research Category:</strong></td>
<td>Not Applicable</td>
</tr>
<tr>
<td><strong>Focus Category:</strong></td>
<td>None, None, None</td>
</tr>
<tr>
<td><strong>Descriptors:</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Principal Investigators:</strong></td>
<td>George M. Hopper</td>
</tr>
</tbody>
</table>

### Publication

Cover photo by Dave Ammon, Mississippi State University
Noxubee National Wildlife Refuge, Brooksville, MS
An abundant and clean supply of water is essential to our livelihood. Throughout the U.S. and abroad, concerns over available water abound. Many southern states are struggling with water issues.

For example, the Georgia Legislature approved a resolution to create a commission that would seek to move Georgia’s border with Tennessee. The resolution, passed this spring, would give Georgia part of the Tennessee River, however, Tennessee may disagree. At the same time, Alabama, Georgia and Florida are disputing over water resources in six rivers. Meanwhile, North and South Carolina are disputing over water from the Catawba River.

Clearly, Mississippi is fortunate to have plentiful supplies of clean water. Our state has water on three sides and most of our water supply is obtained from ground water resources. However, protecting the water resources of the state is imperative to our economic growth and sustaining our quality of life in perpetuity.

The Mississippi Water Resources Research Institute addresses research and outreach efforts targeted at maintaining plentiful, quality water supplies throughout the state. The institute is a hub for information and expertise on water resources issues within the state and region. We do this in full partnership with our public and private cooperators.

The Mississippi Water Resources Research Institute is committed to providing public outreach, educational opportunities, and assisting with economic development activities. This report details many of the activities the institute is addressing on the most pressing water-related problems. Thank you for participating in these endeavors.

George M. Hopper

Director’s Notes
The Mississippi Water Resources Research Institute (MWRRI) provides a statewide center of expertise in water and associated land use and serves as a repository of knowledge for use in education, research, planning, and community service.

The MWRRI goals are to serve public and private interests in the conservation, development, and use of water resources; to provide training opportunities in higher education whereby skilled professionals become available to serve government and private sectors alike; to assist planning and regulatory bodies at the local, state, regional, and federal levels; to communicate research findings to potential users in a form that encourages quick comprehension and direct application to water related problems; to assist state agencies in the development and maintenance of a state water management plan; and to facilitate and stimulate planning and management that:

- deals with water policy issues,
- supports state water agencies’ missions with research on problems encountered and expected,
- provides water planning and management organizations with tools to increase efficiency and effectiveness.

The Mississippi Water Resources Research Institute is a unit of the Forest and Wildlife Research Center, Mississippi State University.
Developing a Reliable Method for Identifying Pre-settlement Wetland Sediment Accumulation Rates: $^{14}$C Dating on Bulk Lake Sediments and Extracts

Gregg Davidson, Geology and Geological Engineering, University of Mississippi

Carbon 14 is often used to date specific layers in lake sediments. However, problems in this type of dating can result in erroneous calculated ages. Four separate sedimentation regimes were identified while researching the history of Sky Lake, an oxbow lake in northwestern Mississippi. Scientists incorporated $^{14}$C activities from bulk sediment samples and collection of deeper cores from the open water region of the lake. This allowed scientists to completely map the history of sedimentation in the lake from the time it was abandoned as an active meander bend to the present. Items identified for analysis included: sand, deposition while still part of an actively flowing system, abandonment from the river system with a relative high sediment accumulation rate from seasonal flooding, migration of the river away from the lake with a subsequent drop in the rate of accumulation, and post land clearing with a 50-fold increase in the rate of sediment accumulation.

Using time intervals prior to land clearing, 97 percent of the lake’s history can be represented. This period lasted upwards of 3600 years during which time approximately 120 cm of sediment accumulated in the lake. In the last 100 to 120 years, since the land began to be cleared, an equivalent thickness of sediment has been added, doubling the total sediment thickness. Radioisotope data and recent observations of sediment accumulation over the past five years indicate that the 50-fold increase in sediment accumulation rate continues unabated.
Assessing the Effectiveness of Streamflow Augmentation in the Sunflower River to Maintain Water Quality and Wetland Integrity

Gary Ervin, Biological Sciences; Todd Tietjen, Wildlife and Fisheries, Mississippi State University

The Big Sunflower River is listed on Mississippi’s Clean Water Act 303(d) as an impaired waterbody. Substantial decreases in the Sunflower River’s late summer/early autumn base flows, as a result of agricultural withdrawals from the Mississippi River Valley Alluvial Aquifer, contribute to the river’s impairment. The objective of this project is to provide a quantitative ecological evaluation of wetland and water quality impacts resulting from groundwater supplementation to a major stream in the Lower Mississippi Alluvial Stream.

Scientists monitored water quality and vegetation data in a small set of target wetlands and stream reaches along a longitudinal gradient from just upstream of groundwater augmentation wells to just north of Indianola, MS. Overall findings suggest that there are modest improvements in the overall system associated with augmented stream flow. Water quality parameters generally remained in an acceptable range during periods of flow augmentation. There were also indications of improved riparian vegetation communities in reaches of the river which have received supplemental flow for years. The underlying problem of over pumping of groundwaters is not addressed by flow augmentation but does provide some value in remediating these withdrawals.

This research has benefited the Yazoo-Mississippi Delta Joint Water Management District. The District is benefitting from the quantitative evaluation of the ecological effects of their water management efforts. The information is also providing guidance on how to best plan future activities. Results of this research increased the efficacy with which water district managers can plan and implement programs to augment surface water flows and storage within the Lower Mississippi Alluvial Valley.
Riparian wetlands are widely regarded as efficient scavengers of a broad range of contaminants. Confidence in the ability of riparian zones to buffer anthropogenic inputs has derived primarily from studies of active inflow and outflow of chemical-laden water and sediment entering and exiting riparian systems. While such studies document short-term scavenging of specific chemicals, they tell little about the permanence of sequestration. In Sky Lake, an oxbow lake-wetland in the Delta region of Mississippi, sediment cores representing 100 years of accumulation contain evidence that inorganic pesticides applied in the past were not permanently sequestered in the wetland surrounding the lake. Lead and arsenic are clearly present in open water sediments deposited approximately 75 years ago and are absent in the wetland sediments. The age of these sediments and elevated concentrations match historical records of lead and arsenate used for boll weevil control in surrounding cotton crops. The geomorphology, sediment distribution, and hydrology suggest that these contaminants could not have reached the lake without depositing a significant mass of contaminated sediment within the wetland. Secondary processes appear to have remobilized and flushed lead and arsenic from the wetland into the open water environment where deposition and burial resulted in permanent sequestration.

Hampton Lake, an oxbow lake in the Delta, was selected based on satellite imagery and ground reconnaissance for sediment sampling. Several 3-m cores were collected. When no lead or arsenic spikes were observed, it was determined that deeper samples were needed. Five-m cores were collected, sectioned, and dried in preparation for digestion and analysis. Arsenic (As), cobalt (Co), copper (Cu), and nickel (Ni) were all found at the same depth though lead was not elevated within the same zone. Another set of samples below this zone are being reprocessed for analysis to replace those that were contaminated during sample preparation.
Water Quality and Floristic Habitat Assessments in the Coldwater and Sunflower River Basins: Comparing Traditional Measures of Water and Habitat Quality to Index of Biotic Integrity

Findings

Todd Tietjen, Wildlife and Fisheries; Gary N. Ervin, Biological Sciences, Mississippi State University

The Coldwater and Sunflower Rivers in Northwest Mississippi are listed on the EPA Section §303(d) list of Impaired Waterbodies for Mississippi. Different river segments and tributaries in the basin are listed as impaired by biological impairment, nutrients, low dissolved oxygen, organic enrichment, pesticides, pathogens, and sediments. Total maximum daily loads have been developed for impaired reaches in the Coldwater and Sunflower River Basins, and water quality improvements are being implemented. Stream quality reference conditions are also being established based on industrial and engineering inspection scores rather than the narrative standards used in the past. This project will refine the development of water quality standards in the Lower Mississippi Alluvial Valley using a combination of additional measures of system status. Scientists will evaluate the incorporation of traditional measures of water quality and stream/river habitat quality measurements, such as floristic quality assessments or riparian areas, with the fish-based data that has already been collected to improve the establishment of appropriate water quality standards. It is expected that this research will enhance management of Lower Mississippi Alluvial Valley surface waters for human use, wildlife value, and water quality, as well as facilitate the administrative determination of water quality standards.

Yazoo Mississippi Delta Joint Water Management District personnel are assisting with water quality sampling. This sampling includes the collection of dissolved oxygen and temperature data from streams in the Mississippi Delta Region. Vegetation monitoring has been completed and the data is being analyzed. Analysis of all collections will be incorporated in a final report that can be useful for water district managers in planning and implementing programs to preserve and enhance water quality.
MWRRI-funded Projects

Climatological and Cultural Influences on Annual Groundwater Decline in the Mississippi Delta Shallow Alluvial Aquifer: Modeling Potential Solutions
Charles L. Wax, GeoSciences; Jonathan W. Pote, Agricultural and Biological Engineering; Joseph Massey, Plant and Soil Sciences, Mississippi State University; and Dean Pennington, Yazoo Mississippi Delta Joint Water Management District

This project seeks to determine the causes of short-term aquifer declines, cultural water uses and climatological processes, with a conscious effort to exclude the effects of river recharge or extraction. Maximizing use of rain to substitute for groundwater is definitely an alternative when water demand in dry years for agriculture becomes an even more serious issue.

Water use from the delta aquifer has been quantified by crop, acreage, and irrigation method. A relationship between growing season rainfall and irrigation water use has been
developed to link interannual variations in water use to variations in climate rainfall. A complete prototype water use model has been completed using acreages, irrigation methods, and management strategies in place during 2006 in Sunflower County to predict annual demand for cotton, rice, soybeans, corn, and catfish.

Growing season climate data for the past 45 years were used to run the water demand model for a 45-year (2008-2053) period to assess aquifer drawdown and recharge characteristics annually and cumulatively over the long-term. Changes in acreages of the major crops, specific irrigation methods, and water management strategies were used to create various scenarios, then conduct multiple model runs to assess the effects of the instituted changes on aquifer drawdown and recharge characteristics over the long-term period.

A Continuation of Climatological and Cultural Influences on Annual Groundwater Decline in the Mississippi Delta Shallow Alluvial Aquifer: Modeling Potential Solutions (Year Two)

Charles L. Wax, Geosciences, Jonathan W. Pote, Agricultural and Biological Engineering, Joseph Massey, Plant and Soil Sciences, Mississippi State University; and Dean Pennington, Yazoo Mississippi Delta Joint Water Management District

MWRRI-sponsored research in the previous year resulted in a model that can simulate the effects of climatological variability, crop acreage changes, and specific irrigation methods on consequent variations in the water volume in the aquifer. The objective of this research is to continue development and refinement of the model by using 2007 climatological and water use data to validate the model results and to then use the model to test and recommend specific management strategies aimed at stabilizing the drawdown in aquifer water volume. The simulation model will be a valuable tool that can be easily used to reflect climatic variability and changes in the cultural practices in the region, and easily modified as new information becomes available. The model will enable management decisions to be made that will allow sustainable use of the groundwater resource.
MWRRI-funded Projects

Multi-scale Evaluation and Analysis of Precipitation Patterns over the Mississippi Delta
Jamie Dyer, Geosciences, Mississippi State University and Dean Pennington, Yazoo Mississippi Delta Joint Water Management District

The Mississippi River floodplain in northwestern Mississippi, often referred to as the Mississippi Delta, is extremely important for regional economic stability and growth due to the widespread agriculture in the area. In terms of water resource management and climatological precipitation research, quantitatively defining the biases associated with available precipitation data is critical in choosing which water source to use for a given application. These precipitation patterns should be reevaluated in terms of duration, frequency, and extent. Including long-term data from surface gauges along with shorter-term but higher resolution radar-derived rainfall estimates allow for a detailed analysis of past and current precipitation trends. This knowledge will lead to a better understanding of rainfall trends and patterns and potentially better prediction of future rainfall.

The results of conducted research can be directly used by water resource managers as well as local and regional agricultural consultants and departments to identify local areas that are more or less sensitive to rainfall during the summer growing season. Agricultural producers in the region as well as planners in the Yazoo Mississippi Water Management District and the Mississippi Department of Environmental Quality will benefit from the model for forecasting. Additional results offer winter patterns that can be identified to quantify recharge rates of groundwater systems.
History of USGS-funded Projects

Over the past five years, research topics have included water quality, groundwater flow and transport, and climate and hydrologic processes. The topics have focused on non-point pollution, sediments, invasive species, management and planning, nutrients, pesticides, toxic substances, surface water, water use, and climatological processes. This research has resulted in 23 presentations made at the Annual Mississippi Water Resources Conference, 26 written papers and final reports submitted, and 17 peer-reviewed journal articles. Two master’s students wrote theses based on their USGS research. Training potential has included one high school student, 24 undergraduate students, 26 master’s students, and 11 doctoral candidates. There were 18 assistant professors, 13 associate professors, and 3 professors performing research at four Mississippi universities.

Presentation topics at past conferences have included surface water quality, wetlands, modeling, invasives, agriculture, sedimentation, wastewater and water treatment, delta groundwater, and flooding and water supply. A student competition was initiated in 2007 and implemented again in 2008 for oral and poster presentations. Student winners have represented Mississippi State University, University of Mississippi, Jackson State University, Clemson University and Ohio State University.
The Mississippi Water Resources Research Institute builds partnerships with the private sector, county and municipal governments, and economic development agencies to identify and pursue water-related economic development opportunities in Mississippi. The Institute plays a key role in defining potential projects and determining their likely economic feasibility and potential. Once it is determined that a project is economically feasible and there is local or regional support, these water development projects often become long-term, multi-disciplinary efforts that utilize expertise from across the State.

**Economic Development**

**Smith County Lake Study**

*Jeff Ballweber and Mary Love Tagert, Mississippi Water Resources Research Institute; Jonathan Pote, Agricultural and Biological Engineering; Jon Rezek, Finance and Economics; Steve Grado, Forestry; Garen Evans and Darren Hudson, Agricultural Economics; and Darrel Schmitz and James May, GeoSciences, Mississippi State University*

Working closely with the U.S. Forest Service and the Bienville Resources and Development Council (an interlocal agreement between Smith, Jasper, Rankin, and Simpson counties), this project is identifying and evaluating sites in Smith County that could be developed into a multi-purpose lake. As part of a master planning effort, the project is also evaluating facilities and amenities that could be directly or indirectly associated with the lake to make it a regional economic development hub for all counties participating in the council. Amenities that were evaluated included water-related structures such as docks and piers, marinas, and boat ramps; land-based facilities such as cabins, camping areas, and structures for recreational activities; residential areas; a conference center; a lodge(s); and complementary commercial establishments.
Using a 2007 PricewaterhouseCoopers report, economic and fiscal impacts from residential activities at the lake were estimated to establish patterns of residential development expected near the proposed Smith County/Bienville National Forest Lake. Data from Lake Eddins was collected from the Jasper County Tax Assessor to estimate the distribution of home values and associated household incomes of residents that would populate the proposed site. PricewaterhouseCoopers estimates were combined with Lake Eddins property tax data to determine economic impacts attributed by new residents. These economic impacts were used to gauge the value of sales tax revenues generated by the project. Another component of the residential analysis involved calculating the property tax implications. In addition to presumed residential activities, estimates from recreational activities planned at the lake and associated facilities were also necessary. Again, the PricewaterhouseCoopers report was used to estimate the number of visitors to the site. Also surveyed were several recreational lakes in Mississippi to estimate typical spending patterns by recreational visitors. The combined visitor numbers and expenditure patterns were used to arrive at estimates of economic impacts of visitors on the region. Economic impacts were then used to extrapolate an estimate of the additional sales tax revenue expected from the project.

From all studies, the scientists found that the proposed lake and associated residential and recreational activities, including business and infrastructure development will generate $183 million (2006 dollars) in future sales. A major source of the revenue would be generated from new residents and construction of the required infrastructure. These two activities would provide a very significant economic stimulus to the region.

Part-time residents and recreational visitors will have a minor impact on the region. Approximately 209 full- and part-time jobs will be created by the lake’s economic stimulus with the majority coming from spending by new residents. Jobs created by the construction of the lake and related infrastructure are considered temporary; however, the average of 58 full-and part-time jobs was skewed with approximately 385 full- and part-time jobs being created in year 1 of the project and about 30 full- and part-time jobs being supported by construction during year 20, the last year of the project.
Grenada Lake Economic Development Project
Mary Love Tagert, Mississippi Water Resources Research Institute; Jon Rezek and Ben Blair, Finance and Economics; Wayne Wilkerson, Landscape Architecture, Mississippi State University

The Grenada Chamber of Commerce contacted the Mississippi Water Resources Research Institute for assistance in promoting economic development around Grenada Lake, a U.S. Army Corps of Engineers lake. The operation of the lake began in 1954 to help control flooding in the Yazoo River Basin. The 90,000-acre multi-use project is managed through the Corps’ Vicksburg District for flood control, public recreation, conservation of fish and wildlife, and public forests. Grenada Lake is also home to Hugh White State Park and a recently constructed 18-hole golf course. The Chamber sought help in working with the Corps to promote economic development based on the lake’s numerous recreational opportunities and bountiful natural resources. The MWRRI led two public meetings to obtain feedback on amenities and opportunities Grenada’s citizens would like to see around the lake. The MWRRI then teamed with Mississippi State University’s Departments of Landscape Architecture and Finance and Economics to develop a preliminary master plan and conduct economic and marketing feasibility studies, respectively.
Southeastern Regional Small Public Water Systems Technical Assistance Center (SE-TAC)
Jeff Ballweber and Kim Steil, Mississippi Water Resources Research Institute; Amy Schmidt, Department of Agricultural and Biological Engineering, Mississippi State University; Jonathan Pote, Mississippi Agricultural and Forestry Experiment Station

The Mississippi Water Resources Research Institute continues to recognize the need for assisting small public water systems in Mississippi and the southeastern United States to provide safe, clean drinking water to the public. The Southeastern Regional Small Public Water Systems Technical Assistance Center (SE-TAC), funded by the Environmental Protection Agency, was established in 2000 and has been administered by the MWRRI at Mississippi State University. SE-TAC works with state and regional agencies to assist small public water systems in acquiring and maintaining the technical, financial, and managerial capacity to provide safe drinking water and meet the Safe Drinking Water Act’s public health protection goals. SE-TAC has adopted an applied approach to directly and meaningfully supporting small public water system issues in the southeastern United States. Throughout its existence, SE-TAC has provided nearly $2 million on over 40 projects that have directly assisted small drinking water systems across the southeast region of the United States. Hundreds of small water systems have received training and assistance with technical, financial and managerial issues through SE-TAC funded projects.

As county and local governments begin to take a more active role in addressing nonpoint sources of water pollution, it is important to accurately and fully quantify the potential water quality benefits of various non-regulatory management alternatives. The Mississippi Water Resources Research Institute works with state and regional agencies to design projects to meet these needs.
The informal Luxapallila Creek Watershed Alliance was formed to bring local stakeholders together to refine, implement, and expand the Luxapallila Creek Watershed Implementation Plan created by the Tennessee-Tombigbee River Basin Team. The plan seeks to protect and restore water quality in the Luxapallila Creek Watershed. As part of this project, high resolution imagery was collected for most of the Luxapallila Creek Watershed and distributed to local and regional stakeholders participating in the Alliance. Geographic information systems (GIS) technologies were used to bring stakeholders together by encouraging them to share their data with other stakeholders for the purpose of addressing current water quality issues within the watershed and developing a water quality protection strategy for the future.
This multidisciplinary project is funded through the National Oceanic and Atmospheric Administration’s Northern Gulf Institute and focuses on using spatial technologies and high performance computing to improve water quality predictions of surface water runoff models. The project study area is the Tennessee-Tombigbee-Mobile River Basin. Institute personnel have assisted with stakeholder interaction and outreach in these areas and provided geospatial data support for the modeling effort. The Institute has worked with MSU’s Department of Civil and Environmental Engineering to provide project updates to interested local and regional stakeholders. We have also obtained feedback from decision makers in the study area on how model results can be made more useful to them in making management decisions.
Aquatic Plant Management Support for the Pearl River Valley Water Supply District
Mary Love Tagert, Mississippi Water Resources Research Institute; John D. Madsen, GeoResources Institute, Mississippi State University

This is an ongoing project conducted with MSU’s GeoResources Institute to monitor and map the distribution of aquatic vegetation throughout the Ross Barnett Reservoir. At 33,000 acres, the reservoir is Mississippi’s largest surface water impoundment and serves as the drinking water supply for Jackson, Mississippi. The Pearl River Valley Water Supply District (PRVWSD) manages the Ross Barnett Reservoir, its recreational amenities, and water and sewer services for approximately 50 surrounding subdivisions. In recent years, invasive species have become an increasing problem, clogging navigation channels, reducing recreational opportunities, and limiting access for users. The PRVWSD requested the Mississippi Water Resources Research Institute’s assistance in assessing the distribution of aquatic vegetation, monitoring the spread of invasive species, and evaluating ongoing treatment efforts throughout the reservoir. During the first plant survey in 2005, 19 plant species were observed. Alligatorweed was the most frequently detected species in 2005, and the native plant American lotus was the most frequently detected species in both the 2006 and 2007 surveys. However, alligatorweed was the most frequently detected exotic invasive plant species in both 2006 and 2007. Due to lack of rainfall, water levels have decreased in 2006 and 2007, limiting access to shallow water areas and thus reducing the number of data points. Scientists may explore the use of remote sensing to examine areas that are currently inaccessible by boat and validate estimates of certain species such as alligatorweed. This project is continuing to monitor the aquatic plant distribution in the reservoir and assess any changes or spread of nuisance species populations, with particular focus on hydrilla, which was first detected in 2005. Management efforts by the PRVWSD are continuing to control nuisance species and promote the growth of more desirable native species.


Advisory Board

Mr. Jan Boyd  
Mississippi Department of Marine Resources

Mr. Tom Bryant  
Pickering Incorporated

Mr. Jamie Crawford  
Mississippi Department of Environmental Quality

Dr. Pat Deliman  
CEERD-EP-E

Mr. Carey Hardin  
Clearwater Consultants

Mr. Kim Harris  
Natural Resource Conservation Service

Mr. Chip Morgan  
Delta Council

Dr. Jami Nettles  
Weyerhaeuser Company

Dr. Dean A. Pennington  
Yazoo Mississippi Delta Joint Water Management District

Mr. Mickey Plunkett  
U.S. Geological Survey

The Honorable Brandon Presley  
Mississippi Public Service Commission

Dr. Mathias J.M. Römkens  
National Sedimentation Laboratory

Dr. LaDon Swann  
MS-AL SeaGrant Consortium

Dr. Paul Tchounwou  
Jackson State University

Mr. Andy Whittington  
Mississippi Farm Bureau Federation
Project Collaborators

Environmental Protection Agency, Office of Ground Water and Drinking Water

Grenada County Chamber of Commerce

Mississippi Department of Environmental Quality

Mississippi Engineering Group

National Oceanic and Atmospheric Administration, Coastal Services Center

Pearl River Valley Water Supply District

Pickering Incorporated

United States Forest Service, National Forests of Mississippi

Yazoo Mississippi Delta Joint Water Management District
## Financial Summary

### July 1, 2007 - June 30, 2008

### Program Component

<table>
<thead>
<tr>
<th></th>
<th>Federal</th>
<th>Non-Federal</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S. Geological Survey grant</td>
<td>$92,335</td>
<td></td>
<td>$92,335</td>
</tr>
<tr>
<td>State appropriations</td>
<td></td>
<td>$207,539</td>
<td>$207,539</td>
</tr>
<tr>
<td>Extramural grants and contracts</td>
<td>$15,000</td>
<td>$101,416</td>
<td>$116,416</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>$107,335</td>
<td>$308,955</td>
<td>$416,290</td>
</tr>
</tbody>
</table>

- **U. S. Geological Survey (22.18%)**
- **State appropriations (49.85%)**
- **Extramural grants and contracts (27.97%)**

---

2008 Annual Report
Discrimination based upon race, color, religion, sex, national origin, age, disability, or veteran's status is a violation of federal and state law and MSU policy and will not be tolerated. Discrimination based upon sexual orientation or group affiliation is a violation of MSU policy and will not be tolerated.
Information Transfer Program-Conferences

Basic Information

<table>
<thead>
<tr>
<th><strong>Title</strong></th>
<th>Information Transfer Program-Conferences</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Project Number</strong></td>
<td>2006MS70B</td>
</tr>
<tr>
<td><strong>Start Date</strong></td>
<td>3/1/2006</td>
</tr>
<tr>
<td><strong>End Date</strong></td>
<td>2/28/2009</td>
</tr>
<tr>
<td><strong>Funding Source</strong></td>
<td>104B</td>
</tr>
<tr>
<td><strong>Congressional District</strong></td>
<td>3rd</td>
</tr>
<tr>
<td><strong>Research Category</strong></td>
<td>Not Applicable</td>
</tr>
<tr>
<td><strong>Focus Category</strong></td>
<td>None, None, None</td>
</tr>
<tr>
<td><strong>Descriptors</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Principal Investigators</strong></td>
<td>George M. Hopper</td>
</tr>
</tbody>
</table>

Publication

1. 2006, Mississippi Water Resources Conference Proceedings, Mississippi Water Resources Research Institute, Mississippi State, MS, CD ROM.
2. 2006, Mississippi Water Resources Conference Program and Abstracts, Mississippi Water Resources Research Institute, Mississippi State, MS, 66 pg.
3. 2007, Mississippi Water Resources Conference Proceedings, Mississippi Water Resources Research Institute, Mississippi State, MS, CD ROM.
4. 2007, Mississippi Water Resources Conference Program and Abstracts, Mississippi Water Resources Research Institute, Mississippi State, MS, 67 pg.
6. 2008, Mississippi Water Resources Conference Program and Abstracts, Mississippi Water Resources Research Institute, Mississippi State, MS, 67 pg.
# Table of Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Program</td>
<td>1</td>
</tr>
<tr>
<td>Speaker Biographies</td>
<td>5</td>
</tr>
<tr>
<td>Poster Session</td>
<td>9</td>
</tr>
<tr>
<td>Session A: Delta Groundwater</td>
<td>23</td>
</tr>
<tr>
<td>Session B: Sedimentation</td>
<td>29</td>
</tr>
<tr>
<td>Session C: Groundwater</td>
<td>33</td>
</tr>
<tr>
<td>Session D: Coastal and Wetlands</td>
<td>37</td>
</tr>
<tr>
<td>Session E: Water Supply</td>
<td>43</td>
</tr>
<tr>
<td>Session F: Surface Water Quality</td>
<td>47</td>
</tr>
<tr>
<td>Session G: Agriculture</td>
<td>51</td>
</tr>
<tr>
<td>Session H: Modeling</td>
<td>55</td>
</tr>
<tr>
<td>Session I: Water Supply Systems</td>
<td>59</td>
</tr>
<tr>
<td>Session J: Invasives</td>
<td>63</td>
</tr>
</tbody>
</table>
PROGRAM

Tuesday, April 15

7:30 a.m. Continental Breakfast - Salon A

8:30 a.m. Climatology Change and Water Availability
          George Hopper, Moderator
          Director, Mississippi Water Resources Research Institute
          Ed Martin

8:45 a.m. Chief, Customer Affairs Branch
          National Oceanic Service, National Oceanic and Atmospheric Administration
          Tom Armstrong

9:05 a.m. Senior Advisor, Global Change Programs
          U.S. Geological Survey
          Charles L. Wax

9:25 a.m. Professor of Geography and State Climatologist
          Mississippi State University
          Donn Rodekohr

9:45 a.m. Research Associate, GIS and Remote Sensing
          Department of Agronomy and Soils, Auburn University

10:05 a.m. Break - Salon A

10:30 a.m. Poster Session

Barbara Ambrose, The bi-national HABSOS
Nestor R. Aznola, George F. Pessoney, and Carmen L. Hernandez; Assessing water quality and
phytoplankton in streams of the leaf river and black creek watersheds
Hamid Borazjani, Susan Diehl, Mary Hannigan, and M. Lynn Prewitt; Long-term performance of
a pump and treat system at a wood treating site
John Brooks and Ardeshir Adeli, Small farm plots and application of simulated rain to
determine the potential for bacterial runoff after poultry litter surface application to
bermudagrass
Ayanangshu Day and Benjamin S. Magbanua, Sensitivity analysis of simultaneous
nitrification-denitrification process by simulation with activated sludge model number one
Marianne K. Burke, Mark H. Eisenbies, Charles A. Harrison, and Hal O. Liechty
Primary productivity, hydro period, and nutrient cycling in four flood-plain forest
communities on a blackwater river
Curtis Gebhard and Katherine Stone, Interactions between ground water and surface water
in the Bogue Phalia near Leland, Mississippi, Summer 2007
Jeffrey Graschel, National Weather Service flood inundation mapping
Kim S. Perkins, John R. Nimmo, Richard H. Coupe, Claire E. Rose, and Michael A. Manning,
Potential for recharge in agricultural soils of the Mississippi Delta
Germania Salazar-Mejia, Jorge A. Ramirez, Luz S. Cadavid, and Jairo N. Diaz-Ramirez; Aerobic-
an aerobic lagoon evaluation in a small rural community in Columbia, South America
Angela Sallis, The phytoplankton monitoring network
Todd Tietjen and Gary Ervin, Big Sunflower River Water Quality Assessments Following
Streamflow Augmentation
K. Van Wilson Jr. and Michael G. Clair II, 1:24,000-scale watershed boundary dataset for
Mississippi

student presenters italicized

36th Annual Mississippi Water Resources Research Conference
<table>
<thead>
<tr>
<th>Time</th>
<th>Concurrent Session</th>
<th>Concurrent Session</th>
</tr>
</thead>
</table>
| 11:30 a.m. | Luncheon                                                                          | Brandon Presley, Keynote Speaker  
Northern District Public Service Commissioner |
| 12:45 p.m. | **Session A: Delta Water Resources**  
Charles L. Wax, Climatological and cultural influences on annual groundwater decline in the Mississippi Delta shallow alluvial aquifer  
Heather L. Welch, Influence of surface-water recharge on the potential for agricultural nutrient and pesticide transport to the Mississippi River alluvial aquifer, Northwestern Mississippi  
Claire E. Rose, Use of a field method for determining hydraulic conductivity in soils in the Bogue Phalia Basin in the Mississippi River alluvial plain | **Session B: Sedimentation**  
Russell Beard, Moderator  
John J. Ramirez-Avila, Sediment transport analysis using HEC-RAS 4.0  
Jeremy A. Sharp, Sediment budget template applied to Aberdeen pool  
Heath Avery, Vegetated swales and their effect on agricultural stormwater flow rates, a field verification of the FarmLatis Conservation Planning Tool |
| 2:05 p.m.  | Break - Salon A                                                                   | Amphitheater  
Concurrent Session  
Session D: Coastal and Wetlands  
Barb Kleiss, Moderator  
Seiji Miyazawa, Effects of landscape factors on limnological conditions of flood-plain lakes in the Yazoo River Basin  
Gregg Davidson, Contaminant transport through riparian wetlands  
Greg Brown, Evaluating water supply needs in rebuilding the Mississippi Gulf Region  
Russell Beard, Bi-national harmful algal blooms observing system (HABSOS) and the phytoplankton monitoring network |
| 2:25 p.m.  | Antonio L. Cordeiro, Nitrate in groundwater in a recharge area of Guarany aquifer in Brazil | Paradigm  
Lindy Rawlings, Upper Leaf River basin base flow study: A preliminary study for surface water/groundwater interactions within the Pascagoula Basin  
Jonathan R. McMillin, An overview of the geology and hydrology of a proposed impoundment of the Upper Sand Creek, Choctaw County, Mississippi |
| 2:45 p.m.  | 2:45 p.m.                                                                          | 2:45 p.m.                                                                          |
| 3:05 p.m.  | 3:05 p.m.                                                                          | 3:05 p.m.                                                                          |
| 3:25 p.m.  | 3:25 p.m.                                                                          | 3:25 p.m.                                                                          |
| 3:45 p.m.  | 3:45 p.m.                                                                          | 3:45 p.m.                                                                          |
**PROGRAM**

**Tuesday, April 15 (continued)**

<table>
<thead>
<tr>
<th>Time</th>
<th>Concurrent Session</th>
<th>Concurrent Session</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>4:05 p.m.</strong></td>
<td>Session E: Water Supply</td>
<td>Session F: Surface Water Quality</td>
</tr>
<tr>
<td></td>
<td>Sam Mabry, Moderator</td>
<td>Glenn Odom, Moderator</td>
</tr>
<tr>
<td><strong>4:05 p.m.</strong></td>
<td><em>Jairo N. Diaz-Ramirez,</em> The Mobile River Basin: A review of physiographic, climatic, water quantity, and water quality characteristics</td>
<td><em>Leili Gordji,</em> Movement of water pollutants in Sardis Lake</td>
</tr>
<tr>
<td><strong>4:25 p.m.</strong></td>
<td><em>Jared K. McKee,</em> A water budget: Tenn-Tom Waterway from Whitten Lock to Heflin Lock and Dam</td>
<td><em>David R. Johnson,</em> River continuum concept and water quality stressor identification</td>
</tr>
<tr>
<td><strong>4:45 p.m.</strong></td>
<td></td>
<td><em>Todd Tietjen,</em> Comparing index of biotic integrity scores to traditional measures of water quality: Exploring the causes of impairment in streams of the Mississippi Delta</td>
</tr>
<tr>
<td><strong>5:05 p.m.</strong></td>
<td>Adjourn</td>
<td></td>
</tr>
</tbody>
</table>

**Wednesday, April 16**

<table>
<thead>
<tr>
<th>Time</th>
<th>Concurrent Session</th>
<th>Concurrent Session</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>7:00 a.m.</strong></td>
<td>Continental Breakfast - Salon A</td>
<td></td>
</tr>
<tr>
<td><strong>8:00 a.m.</strong></td>
<td>Session G: Agriculture</td>
<td>Session H: Modeling</td>
</tr>
<tr>
<td></td>
<td>Richard Rebich, Moderator</td>
<td>William McAnally, Moderator</td>
</tr>
<tr>
<td><strong>8:00 a.m.</strong></td>
<td><em>John J. Read,</em> Effects of harvest management on bermudagrass yield and nutrient utilization in a swine-effluent spray field</td>
<td><em>Ayanangshu Day,</em> Sensitivity analysis of simultaneous nitrification-denitrification process by simulation with activated sludge model number 1</td>
</tr>
<tr>
<td><strong>8:20 a.m.</strong></td>
<td><em>Ardeshir Adeli,</em> Assessing the risks to water bodies from nitrogen vs. phosphorus-based broiler litter strategy</td>
<td><em>Jeffrey Graschel,</em> National Weather Service flood inundation mapping</td>
</tr>
<tr>
<td><strong>8:40 a.m.</strong></td>
<td>Break - Salon A</td>
<td></td>
</tr>
</tbody>
</table>

**MORE SESSIONS ON THE NEXT PAGE**

*student presenters italicized*
<table>
<thead>
<tr>
<th>Time</th>
<th>Concurrent Session I: Water Supply Systems</th>
<th>Concurrent Session J: Invasives</th>
</tr>
</thead>
<tbody>
<tr>
<td>9:00 a.m.</td>
<td>Yi (Frank) Xiong, Water supply calculation of Stonegate Arch</td>
<td>Ryan M. Wersal, Influences of light intensity variations on growth characteristics of parrotfeather (Myriophyllum aquaticum (Vell.) Verdc.)</td>
</tr>
<tr>
<td>9:20 a.m.</td>
<td>Jeannie R.B. Barlow, Decision support tools for implementing and managing regional utilities in Mississippi</td>
<td>Joshua C. Cheshier, Duckweed control in Mississippi waters</td>
</tr>
<tr>
<td>9:40 a.m.</td>
<td>Jason Barrett, Improving the capacity of Mississippi's rural water associations through board management training</td>
<td>John D. Madsen, Littoral zone aquatic plant community assessment of the Ross Barnett Reservoir, Mississippi for 2007</td>
</tr>
</tbody>
</table>

**Additional Events**

- 10:00 a.m. Break - Salon A
- 10:20 a.m. Closing Plenary Session
  - Mickey Plunkett, Moderator
  - Panel Discussion (speakers tentative and subject to change)
- 10:40 a.m. Bill Walker
  - Executive Director, Mississippi Department of Marine Resources
- 12:15 p.m. Barbara Travis, Keynote Speaker
  - Executive Director of the Mississippi World Trade Center
USGS Summer Intern Program

None.
Notable Awards and Achievements
Publications from Prior Years